sized, lies in the clear difference they exhibit for different atomic polarizations and not as accurate determinations of energy distribution. With V_0' set at a fixed value corresponding to an energy lying between the two maxima of Fig. 3(a), the spin resonance was observed as a change in the detector signal height as a function of the microwave frequency. Figure 3(b) shows both the cyclotron and spin resonance obtained in the manner described. As is evident from Fig. 3(a), in contrast to the cyclotron resonance, the spin resonance leads to an increase in the detector signal height. Data were taken at 5.5 and 6.7 GHz, yielding the value $\nu_{spin}/\nu_{cycl} = 1.001\,159 \pm 2$, whose agreement with the accepted value is here significant as much for establishing the validity of the technique as its power.

It is planned to use the above techniques in a $g-2$ experiment. Details of the present work will be published elsewhere.

We wish to thank Professor Dr. W. Paul for his encouragement and interest in this work, and Professor E. N. Fortson[10] of the University of Washington, who initiated studies on the lifetime of the electrons in the trap, and whose observation of an apparently anomalous behavior of this lifetime in the presence of the atomic beam stimulated the study of collision processes in the trap.

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OPTICAL ROTATORY EFFECT IN THE NEMATIC LIQUID PHASE OF *p*-AZOXYANISOLE

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From observations on large, single, liquid crystals it has been found that nematic *p*-azoxyanisole exists in two distinct forms: One rotates the plane of polarization of transmitted light clockwise and the other, counterclockwise by the same amount, in analogy to the right- and left-handed forms of quartz, revealing a significant feature of the structure of nematic liquids which has not previously been reported.

Materials, such as *p*-azoxyanisole, which form nematic liquid crystals have been investigated in recent years in connection with NMR,[1-3] anisotropy of dielectric properties,[4,5] effects of electric fields on optical properties,[6,7] and electrical properties.[8,9] The nematic phase of *p*-azoxyanisole is stable between 116 and 135°C and has the optical properties of a uniaxial single crystal.[10] The liquid is ordinarily broken up into many small regions, randomly oriented with respect to each other, so that the gross properties are comparable with those of a polycrystalline specimen of an ordinary crystalline solid. It is bright when viewed by transmitted light between crossed polarizers but cannot be uniformly extinguished in any orientation. In a thick specimen a modest magnetic field orients the individual crystallites uniformly (see Ref. 1, for example), so that the entire volume becomes single-crystalline.

We have made single liquid crystals by supporting flat drops of liquid 1 cm in diameter and about 1 mm thick on horizontal plates of fire-polished glass cleaned in Caro's acid to remove all organic contaminants from the surface. (We use the word "crystal" here in the same operational sense in which it is used in discussions of the visual observation of crystals under the polarizing microscope, where it means a homogeneous

region of uniform orientation in an anisotropic material.) The p-azoxyanisole was high-purity zone-refined material having a resistivity $>10^{10}$ Ω cm and was observed in an enclosed, transparent oven to minimize temperature gradients. In a horizontal magnetic field H of 2000 G, large single crystals, several mm in extent, are seen when the nematic phase is formed, either by melting the solid or by cooling down from the isotropic phase. When these are viewed along the vertical direction between crossed polarizers, four positions of relative extinction are seen when the polarizers are rotated as a unit through 360° around the vertical axis. There is relative extinction when either polarizer is parallel to H. In addition to the above there is optical rotation by the liquid so that the absolute extinction is much more complete when the polarizers are uncrossed by an angle, θ, which depends on the wavelength and the sample thickness.[11] For example, θ is 8° for thickness 0.5 mm and wavelength 542 mμ. In all cases, two kinds of crystals are present in about equal amounts. One kind rotates the plane of polarization clockwise and the other counterclockwise by the same angle. Figure 1 shows a typical sample of nematic liquid, viewed between polarizers by nonconvergent transmitted light. In both pictures the top polarizer is oriented to transmit light with electric vector $\parallel H$. The two halves of the figure show the same area viewed with two different orientations of the bottom polarizer. On the left the bottom polarizer has been rotated clockwise through 8° from the direction $\perp H$ and on the right it has been rotated counterclockwise through 8°. These angles give the most complete extinction for the respective dark areas in each picture. When the polarizers are mutually perpendicular, the dark and light areas are equally bright, and only the boundaries between, visible as dark lines, indicate that different crystals are present. If the nematic liquid is heated to the isotropic phase and then cooled, a new pattern of crystals forms with different shapes but the same general features shown in Fig. 1.

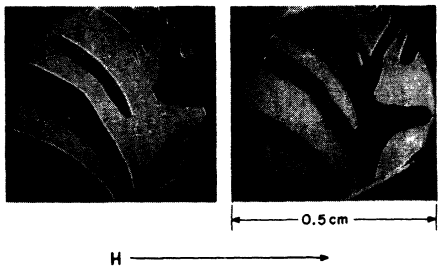

FIG. 1. Observation of p-azoxyanisole by nonconvergent transmitted light. The sample of nematic liquid is 0.5 mm thick and is seen by the light from a tungsten microscope lamp. It is between polarizers. In both pictures the top polarizer is parallel to H. In the left-hand picture the bottom polarizer has been rotated clockwise 8° from the direction perpendicular to H. The right-hand picture shows the same area with the bottom polarizer rotated 8° counterclockwise. $T = 130$°C. The appearance of the patterns is the same for all temperatures within the nematic range.

The rotation is a linear function of sample thickness over the range of thicknesses from 0.25 to 1.65 mm, indicating that the rotatory power is a bulk property. Rotation increases monotonically with decreasing wavelength in the visible part of the spectrum for a given sample thickness, as determined by measurements with interference filters. The rotation at 524 mμ is 1.6 times that at 670 mμ. When H is less than about 500 G, the well-defined crystal boundaries disappear. From 500 to 2500 G the rotation is independent of H.

There are two further observations. (1) Right- and left-handed forms are present at the early stages of growth of the nematic liquid which nucleates and grows from the isotropic phase as small suspended spheres.[12] These invariably have both forms present in the same sphere in nearly equal amounts. (2) A dc electric field of 300 V/cm, applied to the nematic liquid $\parallel H$, causes the amount of left-handed material to grow and the amount of right-handed material to shrink. Reversing the polarity of the dc field has the opposite effect.

All the above effects are seen only when the liquid is in a magnetic field. When the field is removed the uniform orientation disappears and the turbid appearance, characteristic of thick samples of nematic liquids,[13] is seen.

The rotation observed here differs from that reported previously for liquid crystals. Cholesteric liquids have a large optical rotatory power,[13] but for a given wavelength, only one sign of rotation is found for a given liquid. Applying torsion to a nematic liquid can give it a kind of optical rotatory power.[14] Torsional effects should be minimal in our experiments and the sharply bounded areas with opposite signs of rotation are not readily susceptible to explanation by this model. Our tentative conclusion is that the rotatory power of the liquid is an inherent property, determined by the arrangement of molecules[15] in the nematic structure, and that it is similar to the rotatory power of certain solid crystals such as quartz. A more detailed discussion of experi-

ments and the implications for the structure of the nematic phase will be presented in a later article.

The author is indebted to G. Heilmeier and W. Helfrich for valuable discussions of this work.

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OSCILLATIONS PRESENT IN PLASMA-ELECTRON HEATING BY AN ELECTRON BEAM*

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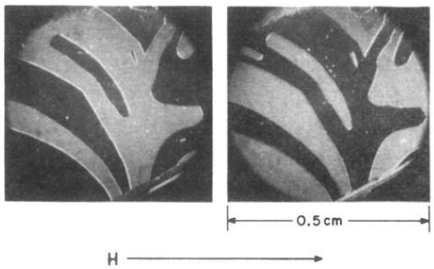
Oscillations of electrostatic fields present when electrons are strongly heated by electron-beam plasma interaction reveal large-amplitude oscillations with $\omega/k_{\parallel} \lesssim v_b$, the electron-beam speed; $\omega \approx \omega_{ce}/10$, where ω_{ce} is the electron gyrofrequency; coherence lengths of roughly a few wavelengths ($\ll$ plasma length); and maximum electrostatic potential in the wave approaching the applied beam voltage. A gross compatibility is found between the observed frequencies and wavelengths and the predictions of a linear theory.

In previous electron beam-plasma interaction experiments,[1] we have observed intense heating of plasma electrons (to a temperature of 100 keV) when confined in a simple magnetic mirror. Similar observations have been made elsewhere.[2] In this Letter, we report on preliminary measurements concerning the frequency, wavelength, correlation time, and correlation length of the plasma-electron oscillations. These measurements support those made elsewhere.[3] In addition, we present direct time-resolved measurements of the electric field, as well as the absolute amplitude of the electric field. These measurements suggest the mechanism by which the heating process occurs.

Two sets of experiments have been performed on the oscillating plasma. In the first set, an impedance-matched probe was placed inside the plasma, and the resulting oscillations were displayed on a traveling-wave-type oscilloscope.[4] The resulting oscillogram, displayed in Fig. 1(a), top, reveals the following information: First, the plasma is not "turbulent," but exhibits coherent oscillations at one frequency that persist for several cycles, then suddenly change phase, frequency, and amplitude in a random fashion. Second, the oscillations generally occur at frequencies near the electron plasma frequency, which in this apparatus is typically somewhat less than the electron cyclotron frequency. Third, the amplitude of the potential oscillations is of the same order as the beam voltage. The observed potentials and correlation lengths are in accord with expectations based on particle-trapping arguments[5]: for $eE_1L \sim eV_b$, background electrons can be trapped in the fluctuating wave leading to a rapid damping of the instability. Here E_1 is the fluctuating electric field strength, L is the correlation length, and V_b is the accelerating potential applied to the electron beam.

A second set of data, obtained with a sampling oscilloscope[6] and displayed in Fig. 1(b), yields information on the auto- and cross-correlation functions for oscillations studied by one and by



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