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MAGNETO-OPTIC DETECTION OF RADIO-FREQUENCY RESONANCE

Optical means of detecting radio-frequency resonance among the Zeeman levels of an atom in a magnetic field have been sought for and discussed by many workers.[1,2,3,4] Bitter[1] was the first to suggest that the intensity, polarisation and frequency of the optical radiation emitted, corresponding to transitions between two levels, are altered when one of the levels is under radio-frequency resonance. Pryce[2] showed that the magnitude of the effect was proportional to the r.f. magnetic field and that it would be rather difficult to observe the optical changes unless the Zeeman components are almost completely resolved. Although the direct observation of the changes in the optical radiation is difficult, it occurred to the authors that the magneto-optic rotation, which is very sensitive, particularly near the absorption line, to the magnitude of the Zeeman splitting, would be an excellent means for detecting the radio-frequency resonance. The order of magnitude of the effect to be expected is discussed below.

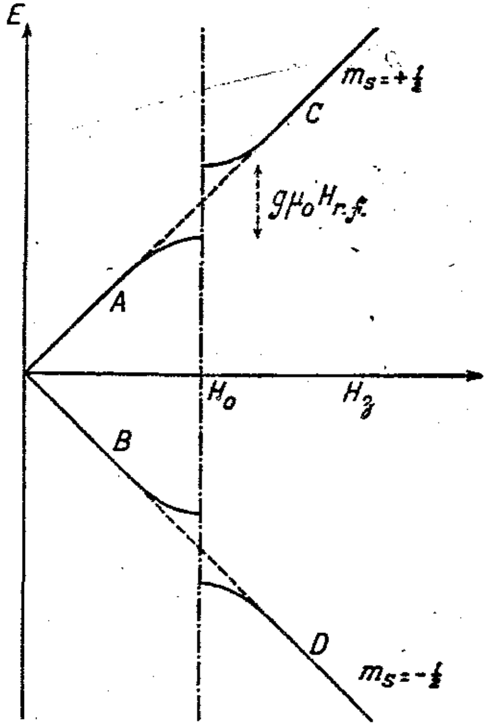

Fig. 1

The energy levels of an atom in the $^2S_{1/2}$ state placed in an r.f. field has been calculated by Pryce[2] to be

$$E = \pm \tfrac{1}{2} \hbar \omega \pm \tfrac{1}{2} [\hbar^2 (\omega_0 - \omega)^2 + (g \mu_0 H_{r.f.})^2]^{1/2},$$

where ω, ω_0 and $H_{r.f.}$ are respectively the applied frequency, the resonant frequency and the r.f. magnetic field. Fig. 1 shows how the energy levels vary with the magnetic field H_z. On approaching resonance the energy difference between $m_s = +\frac{1}{2}$ and $m_s = -\frac{1}{2}$ increases with H_z at a rate slower than it would in the absence of the r.f. field. At resonance the levels are interchanged on account of the absorption and emission of r.f. quanta. Thus, the energy of an atom originally in the state $m_s = +\frac{1}{2}$ increases with the magnetic field and follows the curve A in Fig. 1. At resonance the atom emits an r.f. quantum of energy $\hbar \omega_0$ and goes over to state $m_s = -\frac{1}{2}$ and follows the curve D. Similarly the energy of an atom in the state $m_s = -\frac{1}{2}$ goes from curve B to C by the absorption of a quantum at resonance. The four effective levels given by the curve exist only at resonance and not over a range about resonance as a cursory examination of the curve appearing in Pryce's paper might indicate. It is to be noted that the energy levels are different on either side of resonance. Consequently the Zeeman splitting of the spectral lines arising from transitions from a higher level to a level under the action of an r.f. field will be slightly different before and after resonance. The magnitude of the difference would be approximately $2g\mu_0 H_{r.f.}$

Now the magneto-optic rotation is dependent on the magnitude of the Zeeman splitting of the states of an atom. From the classical experiments of Wood[5] on the magneto-optic rotation in sodium vapour we know that even at 2 A away from the absorption frequency the magnetic rotation is of the order of 0·2° per Oerstead. At moderate radio-frequencies (~ 100 m.c.) it is possible to attain r.f. fields of the order of 1 to 10 Oersteads. The constant magnetic field required to produce resonance at this frequency is about 35 Oersteds. Thus, if the reasoning given above is correct, we should expect to find a sudden change in the magnetic-optic rotation of the order of 0·1° to 2° on crossing the resonance value.

The magnitude of the magneto-optic rotation is also dependent on the transition probabilities associated with the lines whose frequencies are shifted by $g\mu_0 H_{r.f.}/\hbar$. *That these transition* probabilities are not very different from the values when the r.f. field is absent is evident *from Pryce's calculations.* Even if the transition probabilities are much smaller in the r.f. field, it should be possible to detect by electronic methods the variations in the magneto-optic rotation near resonance.

Periodic fractional changes in light intensity of the order of 10^{-7} can be detected by the use of a photomultiplier tube with a tuned amplifier having a narrow band-width. So by amplitude or frequency modulating the r.f. it should be possible to detect changes in rotation of the order of 0·1″ of arc. Experiments have been undertaken to verify the above ideas.

It may be mentioned that the effects discussed above are quite different from the changes in magneto-optic rotation that may occur due to equalisation of population in *paramagnetic resonance* which however will be prominent only at low temperatures.

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1. Bitter, *Phys. Rev.*, 1949, **76**, 833. 2. Pryce, *Ibid.*, 1950, **77**, 136. 3. Kastler, *J. de Physique*, 1950, **11**, 255. 4. Bitter, Brossel and Sagalyn, *Phys. Rev.*, 1950, **79**, 225. 5. Wood, *Physical Optics*, 1934, 702-16.