

THE LIGHT DEPENDENCE OF THE NMR FIELD CYCLING SPECTRA OF
INDIUM PHOSPHIDE DOPED WITH COBALT

KA Walsh, PJ McDonald, EP O'Reilly, FO Zelaya* and B Cockayne†
Department of Physics, University of Surrey, Guildford, Surrey, UK.

*BP Research Centre, Sunbury on Thames, Middlesex, UK.

†Royal Signals and Radar Establishment, Great Malvern, Worcs., UK.

NMR low field cycling has recently been quantitatively demonstrated as a new spectroscopy for defects in III-V semiconductors [1]. In an early study Zelaya showed that white light irradiation of an indium phosphide sample doped with cobalt had a dramatic effect on the spectrum intensity [2]. We have undertaken a more detailed study of this effect. We further confirm that the field cycling spectra are defect related and suggest how the observed light dependence can arise from excitation of Co impurities in the Co^{2+} state to Co^{3+} .

Details of the method and equipment used can be found elsewhere [1,3]. Additionally in this work arrangements were made to direct low power red He-Ne laser light onto the sample. The sample was a single crystal of InP:Co (100 axis // B) obtained from the same boule as that used by Zelaya and described by Skolnick et al [4].

The sample was first cooled to 4K in darkness and the P cross coupling peak measured with a cross relaxation time of 1s. The sample was then illuminated with red laser light whilst a second spectrum was recorded. Typical spectra are shown in figure 1. The P magnetisation is typically 60% greater across the spectrum with the light on. The effect is persistent as an increased spectral intensity can be observed for several hours after the light is switched off. The initial spectrum can be recovered by heating the sample to a temperature of about 100K for a short while. This behaviour mirrors exactly the redistribution in defect centres observed by optical deep level transient spectroscopy [4]. For cross relaxation times longer than 1s, a reduced overall magnetisation was measured. When the experiment was repeated at 12K no light dependence was observed above the noise level for a cross relaxation time of 1s. However, for longer times of order 10-20s a decrease in intensity with light irradiation of order 10% was observed. Spectral intensity growth rates were very similar with and without light. Maximum values were obtained after about 25s compared to 1s at 4K.

The T_1 of ^{115}In was measured at 2.56T over a wide temperature range without any apparent light dependence, increasing from about 0.1s at room temperature to about 4s at 20K. Below 20K it continues to increase. The high field T_1 of P on the other hand is extremely long at low temperature (several hours) and light dependent. Zelaya showed [2] that at 4K and 1.5T it was longer still with light irradiation. DLTS has shown that under light irradiation at low temperature Co impurities in the Co^{2+} state are

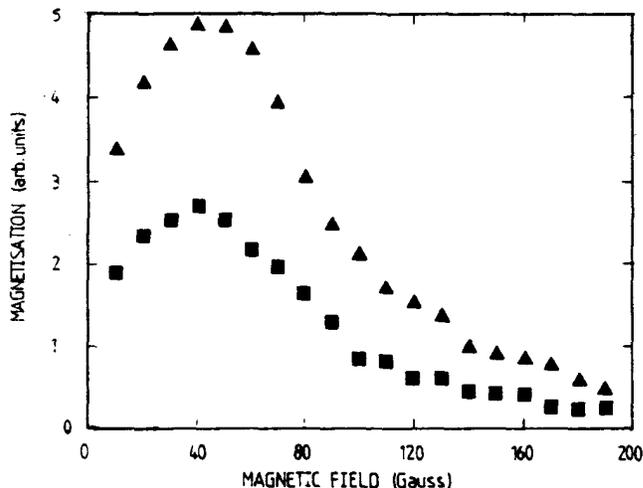


fig 1. P field cycling spectra recorded with (upper trace) and without (lower trace) light.

excited to the higher state Co^{3+} [4]. As Co^{2+} is paramagnetic and Co^{3+} is not Co^{2+} provides an additional spin lattice relaxation mechanism. Hence under optical irradiation the P T_1 is expected to increase as observed. As the In T_1 is relatively fast (unlike P, In is quadrupolar) it is not expected to be sensitive to small changes in Co^{2+} density.

The cross coupling peak at 50G is due to hyperfine interactions around the defect state Co^{2+} and the consequent transfer of magnetisation from In to P at these sites [1]. Its growth competes against In and P spin lattice relaxation. For short cross relaxation times a decrease in either Co^{2+} density or P T_1 reduces the peak intensity. At 4K where the P T_1 is longest and most light sensitive the latter is the dominant effect and leads to the observed increased cross coupling intensity. By 12K P T_1 is reduced sufficiently for the Co^{2+} density to be more critical giving a reduction in peak intensity. A quantitative analysis based on this model is being undertaken with a view to establishing Co^{2+} and Co^{3+} relaxation rates and relative populations.

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