THE EFFECT OF ELECTRIC AND MAGNETIC FIELDS ON THE 7F0→5D0 TRANSITION OF BaClF: Sm2+ USING PHOTON-GATED HOELEBURNING

R. Macfarlane, R. Shelby, A. Winnacker

To cite this version:
R. Macfarlane, R. Shelby, A. Winnacker. THE EFFECT OF ELECTRIC AND MAGNETIC FIELDS ON THE 7F0→5D0 TRANSITION OF BaClF: Sm2+ USING PHOTON-GATED HOELEBURNING. Journal de Physique Colloques, 1985, 46 (C7), pp.C7-537-C7-542. <10.1051/jphyscol:1985796>. <jpa-00225126>

HAL Id: jpa-00225126
https://hal.archives-ouvertes.fr/jpa-00225126
Submitted on 1 Jan 1985

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
THE EFFECT OF ELECTRIC AND MAGNETIC FIELDS ON THE $^7F_0 \rightarrow ^5D_0$ TRANSITION OF $\text{BaClF}: \text{Sm}^{2+}$ USING PHOTON-GATED HOLEBURNING

R.M. Macfarlane, R.M. Shelby and A. Winnacker

IBM Research Laboratory, San Jose, California 95193, U.S.A.

ABSTRACT

A new mechanism of spectral holeburning by 2-step photoionization ("photon-gated" holeburning) has recently been demonstrated. In $\text{BaClF}:\text{Sm}^{2+}$, this leads to permanent spectral holes 25 MHz wide which we have used to measure small linear Stark and nonlinear Zeeman coefficients of the $^7F_0 \rightarrow ^5D_0$ transition of $\text{Sm}^{2+}$. The Zeeman coefficients agree within 4% with those calculated assuming free ion $4f^6$ wave functions for $^7F_0$ and $^5D_0$.

INTRODUCTION

A new mechanism of spectral holeburning ("photon-gated" holeburning) has been demonstrated [1] in $\text{BaClF}:\text{Sm}^{2+}$. This involves 2-step photoionization of $\text{Sm}^{2+}$ and subsequent trapping of the released electron. The resulting holes are permanent, at least on the time scale of days. Stable holes of this kind can be used to measure small frequency shifts [2] as we do here in a high resolution (~10 MHz) study of Zeeman and Stark effects of the $^7F_0 \rightarrow ^5D_0$ transition of the $\text{Sm}^{2+}$ ion at 2K. For these measurements, the total shifts are much less than the inhomogeneous linewidth and could not be measured without the use of holeburning spectroscopy. In $\text{BaClF}$, the $\text{Sm}^{2+}$ ions substitute for $\text{Ba}^{2+}$ at sites of $C_{4v}$ symmetry. [3] An analysis of the emission and excitation spectrum of this material was reported by Gacon et al. [4]
Figure 1. Nonlinear Zeeman effect of the $^{7}F_0 \leftrightarrow ^{5}D_0$ transition of BaCl$_2$:Sm$^{2+}$ for $H_0 \perp C$ using a "photon-gated" hole as a frequency marker.

$^{7}F_0 \leftrightarrow ^{5}D_0$ NONLINEAR ZEEMAN EFFECT

Zeeman experiments were carried out in a superconducting solenoid at fields up to 50 kG. The field was calibrated using $^{19}$F optically detected nmr [5], and the laser scan calibration was made with a 7.5 GHz FSR optical spectrum analyzer. A hole was burned in the 6879A line using $\sim$1W/cm$^2$ of cw dye laser light (width $\sim$1 MHz) for frequency selection and 10 W/cm$^2$ of Ar$^+$ laser light at 514.5 nm for gating. Exposure times were $\sim$1 sec. Holes were detected in fluorescence excitation monitoring the $^{5}D_0 \leftrightarrow ^{7}F_2$ emission at 7277A. The hole was observed to shift quadratically with field as shown in Figs. 1 and 2.
Figure 2. Plot showing the quadratic nature of the hole shift for $H_0 \parallel c$ (0.90 Hz/G$^2$) and $H_0 \perp c$ (0.77 Hz/G$^2$).

A calculation of the nonlinear Zeeman effect was made assuming free ion 4f$^6$ wave functions and using empirical zero field energies in the denominators of a second order perturbation expansion of the magnetic energy, W. Referring to Fig. 3 for the definition of energy denominators we find

$$H_0 \parallel c$$

$$W(^7F_0A_1) = -\frac{4\beta^2}{\Delta_1}H_Z^2$$

$$W(^5D_0A_1) = -\frac{2\beta^2}{\Delta_1}H_Z^2$$

$$H_0 \perp c$$

$$W(^7F_0A_1) = -\frac{4\beta^2}{\Delta_2}H_X^2$$

$$W(^5D_0A_1) = -\frac{2\beta^2}{\Delta_2}H_X^2$$
Since $\Delta_{3,4}$ is approximately five times larger than $\Delta_{1,2}$, the Zeeman shift arises predominantly from the depression of the groundstate due to $7F_0-7F_1$ interaction. The anisotropy of the shift comes from the $7F_1$ splitting which results in $\Delta_2>\Delta_1$ and hence a larger shift for $H_0 \parallel c$. There is a contribution of opposite sign from the excited state $5D_0-5D_1A_2$ interaction which produces a small but measurable effect of $-0.1$ Hz/G². The results we obtain, and a comparison with the simple model calculation is given in Table I. The agreement is seen to be excellent.

**Table I**

<table>
<thead>
<tr>
<th></th>
<th>Expt.</th>
<th>Theor.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hz/G²</td>
<td>Hz/G²</td>
</tr>
<tr>
<td>$H_0 \parallel c$</td>
<td>0.90</td>
<td>0.89</td>
</tr>
<tr>
<td>$H_0 \perp c$</td>
<td>0.77</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Figure 3. Definition of energy denominators for the perturbation calculation of nonlinear Zeeman coefficients, and a schematic diagram of the effect of magnetic and electric fields on the $7F_0A_1$ and $5D_0A_1$ levels. For the Stark shift, the solid and dotted lines correspond to opposite signs of the electric dipole moment.
For these measurements, a crystal was sandwiched between stainless steel electrodes at 2K, and electric fields $E_g$ up to 40 kV/cm applied. In $C_4v$ symmetry, only $E_g \parallel c$ produces level shifts and the observed "splittings" are pseudo-Stark splittings or inequivalent shifts for electric dipoles parallel and antiparallel to the applied field (Fig. 4). The Stark coefficients, expressed as the shift of "up" or "down" dipoles (i.e., one half of the hole splitting) are:

Table II

<table>
<thead>
<tr>
<th>Expt.</th>
<th>$E_g \parallel c$</th>
<th>$E_\perp c$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\pm 36$ MHz/kV cm$^{-1}$</td>
<td>0 MHz/kV cm$^{-1}$</td>
</tr>
</tbody>
</table>

Figure 4. Pseudo-Stark splitting between holes in the absorption of ions with "up" and "down" electric dipoles.

An earlier measurement [3] of this Stark coefficient using conventional fluorescence emission spectroscopy gave a value about a factor of two smaller than reported here. Holeburning provides an increase in precision of 1-2 orders of magnitude in this case. There are very few measurements of Stark coefficient for $f^n$-$f^n$ transitions. We note that
for the $^{3}H_{4} \rightarrow ^{1}D_{2}$ transition of LaF$_3$:Pr$^{3+}$ the effect is about four times larger [6] than that reported here for Sm$^{2+}$. A quadratic shift is expected for $E_{2\perp c}$ but this was not observed. Calculation of Stark coefficients is difficult since they vanish for 4f$^6$ states and arise from small admixtures of the 4f$^5$5d configuration by the noncentrosymmetric component of the crystal field. Such calculations have not been carried out.

REFERENCES


