

Zeitschrift: Archives des sciences [1948-1980]
Herausgeber: Société de Physique et d'Histoire Naturelle de Genève
Band: 27 (1974)
Heft: 2-3: EPR of magnetic ions in metals

Artikel: Effects of the excited crystalline field states in the ESR of Er : Au
Autor: Baberschke, K.
DOI: <https://doi.org/10.5169/seals-739306>

Nutzungsbedingungen

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. [Mehr erfahren](#)

Conditions d'utilisation

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. [En savoir plus](#)

Terms of use

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. [Find out more](#)

Download PDF: 30.01.2026

ETH-Bibliothek Zürich, E-Periodica, <https://www.e-periodica.ch>

EFFECTS OF THE EXCITED CRYSTALLINE FIELD STATES IN THE *ESR* OF *Er*:*Au*

BY

K. BABERSCHKE

Fachbereich Physik, Freie Universität Berlin, Germany

INTRODUCTION

The effect of excited crystalline field states on the relaxation rate of the ground state is well known in insulators. This “Orbach process” is strongly temperature dependent being determined by the energy splitting Δ between the ground state and the first excited crystalline field (c.f.) state [1].

In 1969 Williams and Hirst [2] have determined the c.f. splitting of several rare earth ions in *Au* and *Ag*. In addition in 1969 Hirst [3] has given the general formula for the relaxation rate in a multilevel system of a localized moment, which is coupled to the conduction electrons. The most favoured system for detecting this effect by *ESR* will be *Er*:*Au*. Up to now only the resonance of *Er*, *Dy*, *Yb* (besides the *S*-state ions) was detected in metals. In most of the host metals *Er* shows the smallest thermal broadening. The smallest residual width was observed in *Er*:*Au* [4]. Both facts favour this system because one is able to follow the resonance signal up to high temperatures.

EXPERIMENTAL RESULTS

Previous *ESR* measurements [4] were performed at temperatures below $4.2^\circ K$. In this temperature range the thermal broadening is $b = 2.7 G/K$. The *g*-value of $g = 6.8$ indicates a Γ_7 ground state, which is in agreement with the static susceptibility measurements [2]. Figure 1 shows the resonance signal at 4 and $14^\circ K$. At $4^\circ K$ one observes the hyperfine splitting. At higher temperatures this is smeared out and the error on determining the linewidth increases. Depending on the *Er* concentration we were able to follow the resonance signal up to 20-30 K . Figure 2 shows a break at roughly $6 K$ in the linear temperature dependence of the linewidth. This is attributed to an additional relaxation rate by excited c.f. states. Measurements on other systems *Er*, *Dy* in *Ag*, *Ir*, *Th* are performed and will be published elsewhere [5, 6].

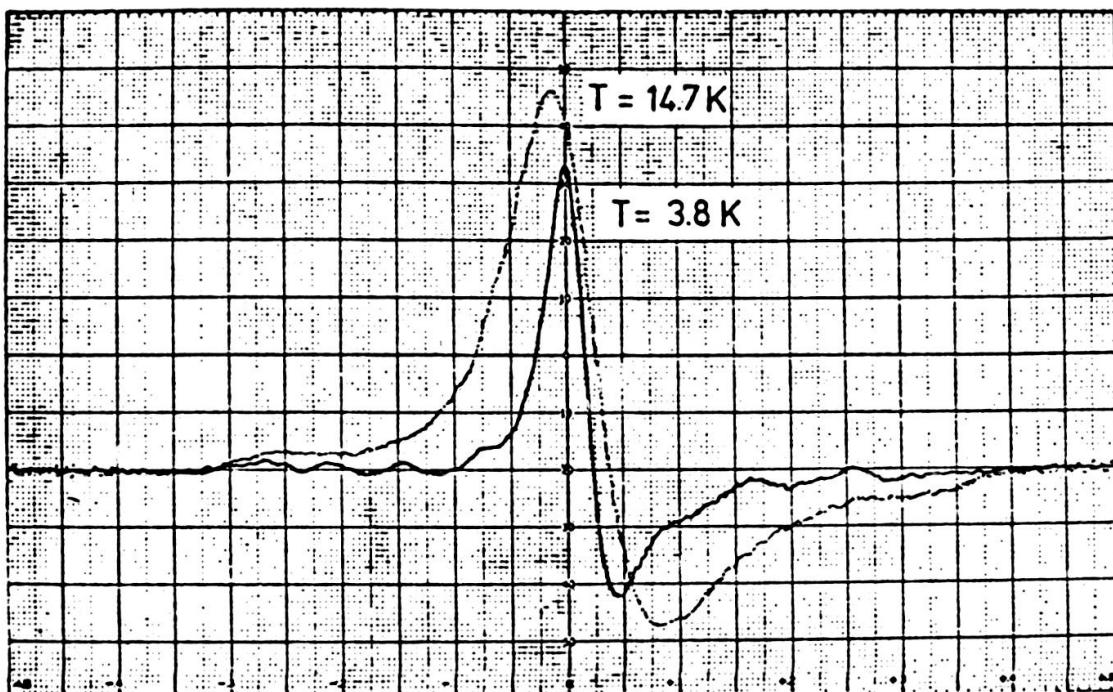


FIG. 1. — ESR signal of 1000 ppm Er:Au at X-band and 100 kHz modulation frequency. $H_0 = 984$ G, $H_{\text{sweep}} = 1$ kG. The spectra at 14.7°K is amplified by a factor of 5.

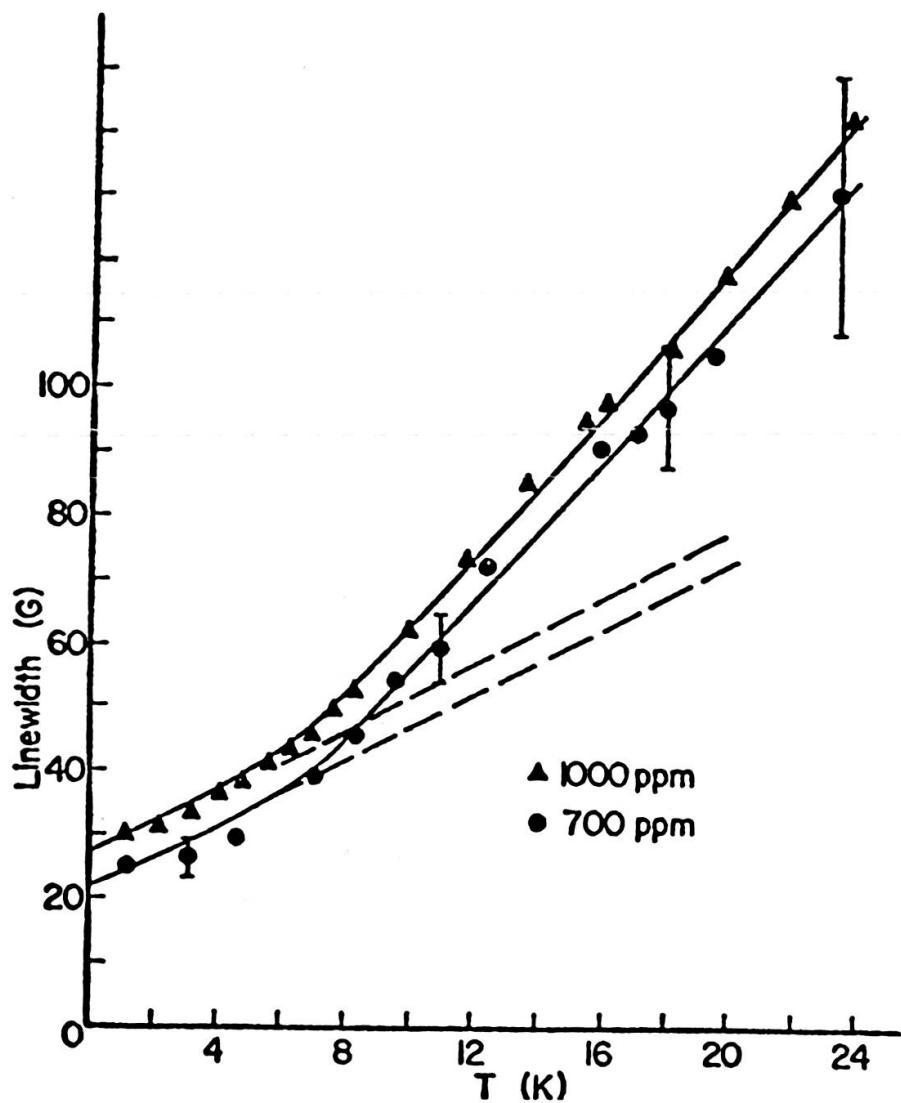


FIG. 2. — Linewidth as a function of temperature. Different Er concentrations show different residual linewidth but the same slope.

DISCUSSION

Susceptibility measurements show the first excited level to be Γ_8 . Labelling the ground state by $|\pm\rangle$ and the excited Γ_8 by $|i\rangle$, we find the thermal broadening ΔH .

$$\Delta H = \frac{\pi}{2g_{\text{eff}} \mu_B} \left[(g_J - 1) \eta (E_F) \right]^2 \langle J^2(q) \rangle (A + B + C) \quad (1)$$

$$A = (\langle + | J_z | + \rangle - \langle - | J_z | - \rangle)^2 k_B T,$$

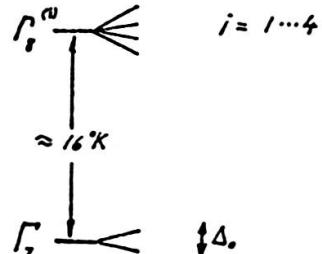
$$B = \frac{1}{2} / \langle + | J_z | - \rangle^2 \left\{ f(\Delta_0) + f(-\Delta_0) \right\}$$

$$C = \frac{1}{2} \sum_i \left\{ (| \langle + | J_z | i \rangle |^2 + | \langle + | J_z | i \rangle |^2) f(\Delta_i^+) + (| \langle i | J_z | - \rangle |^2 + | \langle i | J_z | - \rangle |^2) f(\Delta_i^-) + 2 | \langle + | J_z | i \rangle |^2 f(\Delta_i^+) + 2 | \langle - | J_z | i \rangle |^2 f(\Delta_i^-) \right\}$$

$$\Delta_0 = E(\Gamma_7, +) - E(\Gamma_7, -),$$

$$\Delta_i^\pm = E(\Gamma_8, i) - E(\Gamma_7, \pm),$$

$$f(\Delta) = \frac{\Delta}{e^{\Delta/k_B T} - 1}$$



There are 3 contributions A , B , C to ΔH . A and B are caused only by the Γ_7 ground state. "A" is the so-called "frequency modulation" part of the relaxation rate [7], which becomes exactly zero at zero temperature. The contribution "B" becomes constant at zero temperature and proportional to $\Delta_0 = g\beta_B H_0$. The contribution of the excited c.f. state is given by the term "C". Assuming an overall splitting of $105^\circ K$ [2] we were able to fit the experimental data to the theoretical formula with $\Delta = 16 \pm 6^\circ K$. This is in good agreement with the splitting determined by susceptibility measurements [2]. The big errorbar is caused by the unsensitivity of the relaxation rate on Δ as shown in Figure 3. Similar effects on the relaxation rate in $Er:Au$ are measured by Mössbauer technique [9].

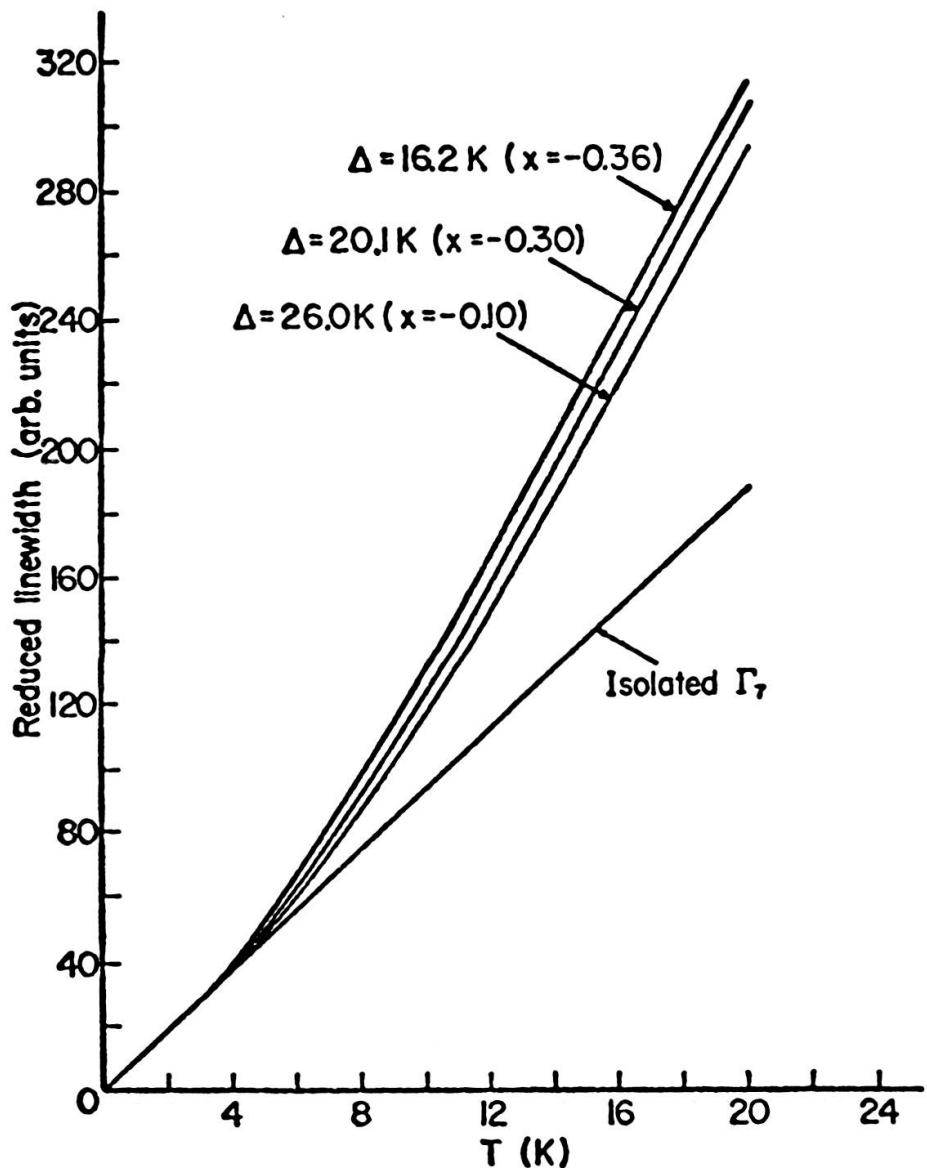


FIG. 3. — Thermal broadening calculated by formula (1). x is a measure of the ratio of the fourth-and sixth-order c.f. parameter [8].

SUMMARY

We reported for the first time the effect of excited c.f. states on the relaxation rates of localized moments in metals by *ESR*. The results show that the c.f. in metals acts in a similar way than in insulators. Furthermore the perfect agreement between theory and data shows by itself that the *ESR* signal is a bulk measurement of the *Er: Au* alloy which means surface effects are small. Further results on the relaxation rate and on the *g*-factor by excited c.f. states are to be published elsewhere [5, 6].

ACKNOWLEDGEMENT

Most of the work was performed at UCLA. It is a great pleasure to thank Prof. R. Orbach, Dr. D. Davidov, and Dr. C. Rettori for the possibility to work in their group. Furthermore I would like to thank Prof. P. Pincus and the Department of Physics for their hospitality extended to me during my stay at UCLA.

REFERENCES

- [1] A. ABRAGAM, B. BLEANEY, *EPR of transition ions*, Oxford 1970 and ref. therein.
- [2] G. WILLIAMS, L. C. HIRST, *Phys. Rev.* **185**, 407 (1969).
- [3] L. C. HIRST, *Phys. Rev.* **181**, 597 (1969).
- [4] J. TAO, D. DAVIDOV, R. ORBACH, E. P. CHOCK, *Phys. Rev. B4*, 5 (1971).
- [5] D. DAVIDOV, C. RETTORI, A. DIXON, K. BABERSCHKE, E. P. CHOCK, and R. ORBACH; *Phys. Rev. B8*, 3563 (1973).
- [6] C. RETTORI, D. DAVIDOV, H. M. KIM, *Phys. Rev. B9* 147 (1974).
- [7] J. DUPRAZ, B. GIOVANNI, R. ORBACH, J. D. RIBY, and J. ZITKOVA in *Magnetic Resonance*, Plenum Press, (1970).
- [9] G. K. SHENOY, J. STÖHR, G. M. KALVIUS., *Solid State Comm.* **13**, 909 (1973).

