

where  $A_1$  and  $A_4$  are functions of  $(r, t)$  only. This result implies that  $F_{14}$  is the only surviving component of a SS electromagnetic field provided we adopt the following definition of a SS electromagnetic field. Here  $F_{ij}$  stands for Maxwell electromagnetic skew tensor.

#### Definition

An electromagnetic field is SS if its 4-potential  $A_i$  is SS in the sense of Takeno, i.e., it has the structure given in (2), in a suitable gauge.

Note that the above result (that only  $F_{14} \neq 0$  in a SS  $F_{ij}$ ) is consistent with the fact that the non-zero components of a general second rank skew-tensor  $F_{ij}$  are given by<sup>1</sup>

$$F_{14} = f_1, F_{23} = f_2 \sin \theta,$$

where  $f_1$  and  $f_2$  are functions of  $(r, t)$  only.

Since the electromagnetic 4-potential  $A_i$  admits arbitrary gauge transformations, we note that in a general gauge, the structure of a SS  $A_i$  is given by

$$A_i = \left( A_1 - \frac{\partial f}{\partial x^1}, -\frac{\partial f}{\partial x^2}, -\frac{\partial f}{\partial x^3}, A_4 - \frac{\partial f}{\partial x^4} \right). \quad (3)$$

Evidently the special structure given in (2) is preserved under the subclass of gauge transformations with  $f = f(r, t)$ .

It is interesting to note that the above definition of SS electromagnetic fields can be used in general relativity to simplify the proof of Birkhoff's theorem in the presence of electromagnetic fields. It is easy to see that in the presence of a SS electromagnetic field, the non-vanishing components of the electromagnetic energy tensor  $T_{ij}$  are given by

$$\begin{aligned} T_{11} &= -I^2/2C, T_{22} = r^2 I^2/2AC, \\ T_{33} &= T_{22} \sin^2 \theta, T_{44} = I^2/2A. \end{aligned} \quad (4)$$

where  $F_{14} = I$ .

For the general SS line-element (1), the field equations

$$R_{ij} = -8\pi T_{ij} \quad (5)$$

and the energy tensor (4), yield, on integration,

$$A = A(r) \quad (6)$$

and

$$AC = H(t), \quad (7)$$

where  $H$  is a function of  $t$  alone. Changing  $t$  to a new variable  $T$  such that

$$T = \int [H(t)]^{1/2} dt \quad (8)$$

and using (7) we get

$$ds^2 = -A(r) dr^2 - r^2 d\Sigma^2 + [A(r)]^{-1} dT^2 \quad (9)$$

which evidently is static. This establishes Birkhoff's theorem in the presence of a SS electromagnetic field.

In classical text-books<sup>2,3</sup>, while obtaining the Reissner-Nordstrom (RN) solution,  $F_{14}$  is shown to be only non-vanishing component of  $F_{ij}$  by assuming the space-time to be static. On the other hand, if we assume the electromagnetic field to be SS, as we have described earlier, it is not necessary to assume the space-time to be static.

The authors are thankful to the referee for his kind suggestions.

October 30, 1980.

1. Takeno, H., *Theory of Spherically Symmetric Space-time*, 1966, p. 4.
2. Eddington, A. S., *The Mathematical Theory of Relativity*, 1960, p. 185.
3. Tolman, R. C., *Relativity Thermodynamics and Cosmology*, 1934, p. 265.

#### D-X SYSTEM OF COPPER BROMIDE MOLECULE

K. PERUMALSAMY, S. B. RAI AND K. N. UPADHYA

Laser and Spectroscopy Laboratory  
Physics Department, Banaras Hindu University  
Varanasi 221 005, India

COPPER bromide molecule is known to have four band systems, namely, A system (5100-4600 Å), B system (4600-4200 Å), C system (4600-3900 Å) and D system (4000-3700 Å) (see refs. 1-2). All these systems involve ground state ( $X^1\Sigma^+$ ) as the lower state. The D system of this molecule was first observed in emission by Rao and Rao<sup>2</sup>. The rotational structure in the (2, 0) and (0, 1) bands of this system was analysed by Rai *et al.*<sup>3</sup> Since the two bands analysed do not involve any common vibrational level, the correctness of the analysis could not be verified. Moreover the structure reported by Rai *et al.*<sup>3</sup> appears to be quite diffuse (due to large slit width) creating more doubt in the analysis. Therefore it is thought worthwhile to restudy the structure of this system in continuation to our previous work on copper bromide<sup>4,5</sup>. We have photographed the structure of (0, 0), (1, 1), (0, 1), (0, 2) and (2, 0) bands under high resolution and the details of this study are given here.

The bands were excited using a 125 watt microwave oscillator. A 99.9% pure (Riedel) copper bromide sample was used. The bands were found developing well when the colour of the discharge was deep violet. The bands were photographed in the second order of a 10.6 m concave grating spectrograph with 0.33 Å/mm dispersion. An exposure of 15 hours

duration was found adequate. Iron arc spectrum in air was used as wavelength measurement standard. The structure was measured using a precise comparator with  $10^{-4}$  mm least count.

TABLE I

A comparison of the combination differences ( $\text{cm}^{-1}$ )

(J)	$\Delta_2 F''$ (J)		$\Delta_2 F'$ (J)	
	(0, 0) band	(2, 0) band	(0, 0) band	(0, 1) band
41	15.87	16.93	15.66	15.72
42	17.32	17.25	16.08	16.08
43	17.63	17.57	16.55	16.65
44	18.03	18.10	17.02	16.95
45	18.52	18.53	17.40	17.36
46	18.89	18.95	17.76	17.70
47	19.30	19.37	18.10	18.05
48	19.73	19.69	18.46	18.42
49	20.12	20.20	18.75	18.68
50	20.50	20.55	19.04	..
51	20.87	20.94	19.55	19.60
52	21.49	21.35	19.90	19.92
53	21.75	21.82	20.42	20.37
54	22.15	22.15	20.80	20.83
55	22.57	22.50	21.22	21.12
56	23.00	22.97	21.46	21.52
57	23.46	23.42	21.80	21.85

Rotational structures in only three bands (0, 0), (0, 1) and (2, 0) were found suitable for the analysis. Rest of the bands involve severe overlappings. Even in the (0, 0) band only 7 A structure from head is free from overlap. The intensity of (0, 0) band is slightly less in comparison to (2, 0) and (0, 1) bands. The (0, 0) band has single head and there are two branches present in the structure. This establishes the transition of this system to be  ${}^1\Sigma^+ - {}^1\Sigma^+$  type and the D state of this molecule is a  ${}^1\Sigma^+$  state. The vibrational isotopic shift in the (0, 0) band of this system is negligible, however due to rotational isotopic shift the structure at higher J becomes diffuse.

The (2, 0) and (0, 1) bands show diffuse double heads. The separation between two heads in the two bands match well with the calculated isotopic shift for  ${}^{63}\text{Cu}{}^{79}\text{Br}$  and  ${}^{63}\text{Cu}{}^{81}\text{Br}$  indicating the two heads due to these two isotopic molecules. The diffuseness is due to the presence of the less abundant molecules  ${}^{65}\text{Cu}{}^{79}\text{Br}$  and  ${}^{65}\text{Cu}{}^{81}\text{Br}$ . Both these bands show the presence of four branches in the structure. A calculation of isotopic shift in these bands indicates that they are two pairs of branches due to two isotopic molecule  ${}^{63}\text{Cu}{}^{79}\text{Br}$  and  ${}^{63}\text{Cu}{}^{81}\text{Br}$ .

For a  ${}^1\Sigma^+ - {}^1\Sigma^+$  transition there should be two branches R and P present in the structure. But due to the use of natural CuBr which contains four isotopic species ( ${}^{63}\text{Cu}{}^{79}\text{Br}$ ,  ${}^{63}\text{Cu}{}^{81}\text{Br}$ ,  ${}^{65}\text{Cu}{}^{79}\text{Br}$  and  ${}^{65}\text{Cu}{}^{81}\text{Br}$ ) with abundance ratio 3:3:1:1, the number of branches will be considerably increased and we could detect two P and two R branches in the (0, 1) and (2, 0) bands due to  ${}^{63}\text{Cu}{}^{79}\text{Br}$  and  ${}^{63}\text{Cu}{}^{81}\text{Br}$  molecules.

The J assignments of the lines were made by comparing the combination differences for the bands

TABLE II

Molecular constants for the D-X system of  ${}^{63}\text{Cu}{}^{79}\text{Br}$  ( $\text{cm}^{-1}$ )

Constants	Present		Reported by Rai <i>et al.</i> <sup>3</sup>		From microwave study <sup>6</sup>
	X state	D state	X state	D state	X state
$B_0$	0.1017	0.0950	0.1004	0.0917	0.10170018
$B_1$	0.1012	..	0.0995	..	0.10124805
$B_2$	..	0.0940	..	0.0907	..
$D_0 \times 10^8$	4.20	4.05	..	..	4.272765
$B_e$	0.1019	0.0952	0.1009	0.0922	0.10192625
$a_e$	0.0005	0.0005	0.0009	0.0005	0.00045214

having common vibrational levels and also from the combination differences calculated using microwave data<sup>6</sup>. The agreement between the combination differences from the (2,0) and (0,0) bands; and (0,0) and (0,1) bands (see Table I) confirms the correctness of our analysis. Our combination differences thus obtained are much different from Rai *et al.*<sup>3</sup> indicating their analysis to be incorrect.

The constants were finally determined using usual graphical method<sup>7</sup>. Our constants for the ground state agree well with the constants reported by microwave study<sup>6</sup>. The constants reported by Rai *et al.*<sup>3</sup> for the ground state differs considerably from the microwave value. Our excited state constants also differs from Rai *et al.*'s<sup>3</sup> value. The constants thus obtained are given in Table II.

June 30, 1980.

1. Ritschl, R., *Z. Phys.*, 1927, 42, 172.
2. Rao, Ramakoteswara and Apparao, K. V. S. R., *Proc. Indian Acad. Sci.*, 1964, 60, 57.
3. Rai, B., Pandey, R. K., Rai, S. N. and Chaudhary, A. K., *Curr. Sci.*, 1971, 40, 459.
4. Mishra, G. P., Tripathi, R., Rai, S. B. and Upadhyaya, K. N., *Ibid.*, 1980, 49, 142.
5. Rai, S. N., Upadhyaya, K. N. and Rai, D. K., *J. Mol. Spectrosc.*, accepted.
6. Manson, E. L., De Lucia, F. C. and Gordy, W., *J. Chem. Phys.*, 1975, 62, 1040.
7. Herzberg, G., *Spectra and Structure of Diatomic Molecules*, D. Van Nostrand Company, New York, 1950.

## THE DISAPPEARANCE OF CESR AND MECHANISM OF SUPERCONDUCTIVITY

S. N. EKBOTE AND A. V. NARLIKAR

National Physical Laboratory, Hillside Road  
New Delhi 110 012

In the earlier papers<sup>1-3</sup> we had reported our results of CESR and spin wave resonance in A-15 superconductors in the normal and superconducting states. It was concluded that the disappearance of CESR and spin wave resonance in the superconducting state was indicative of nonphononic mechanism of superconductivity. In this note we discuss this important conclusion further to point out that our model is in accord with various other findings, inexplicable in terms of the BCS theory<sup>4</sup>.

We first analyse the findings of Schultz *et al.*<sup>5</sup> on CESR studies of Al carried out in the normal and forced normal state<sup>7</sup>. Almost immediately after

Kaplan's calculations<sup>6</sup>, when it became apparent that the CESR studies in the superconducting state could give an insight into the relaxation mechanism of the Cooper pairs, Schultz *et al.* carried out CESR studies on Al in the temperature range of 77 K to 1.4 K. It is worth pointing out that although  $T_c$  of Al is 1.7 K<sup>7</sup>, the CESR observations at 1.4 K correspond to the situation where the metal is in the forced normal state as the applied magnetic field is in excess of the critical magnetic field of Al<sup>7</sup>.

Figure 1 depicts our results for Nb<sub>3</sub>Ge and those of Schultz *et al.* for Al at different temperatures. It is interesting to note that in the case of Nb<sub>3</sub>Ge ( $T_c = 22.65$  K) the CESR line has completely disappeared at 4.2 K while for Al in the forced normal state, the CESR line is markedly reduced in intensity. According to Kaplan<sup>6</sup> and Aoi and Swihart<sup>8</sup>, if the BCS mechanism were operating, the CESR should not have vanished (for Nb<sub>3</sub>Ge at 4.2 K) or nearly vanished (for Al at 1.4 K).

The disappearance of CESR and side absorptions in Nb<sub>3</sub>Ge, we explained<sup>2,3</sup> on the basis of antiferromagnetic coupling resulting in an ordered magnetic state. Both CESR and spin waves in such a state are not expected unless fluctuations are imposed by applying higher magnetic fields and microwave frequencies which would necessarily revert the material normal.

Results of Schultz *et al.* immediately follow the above contention. The near vanishing of CESR in the forced normal state is most likely to be the direct consequence of a phenomenon analogous to the occurrence of the spin flop region involving canting of spins due to the application of the magnetic field in antiferromagnetic materials<sup>9</sup>. A small canting is

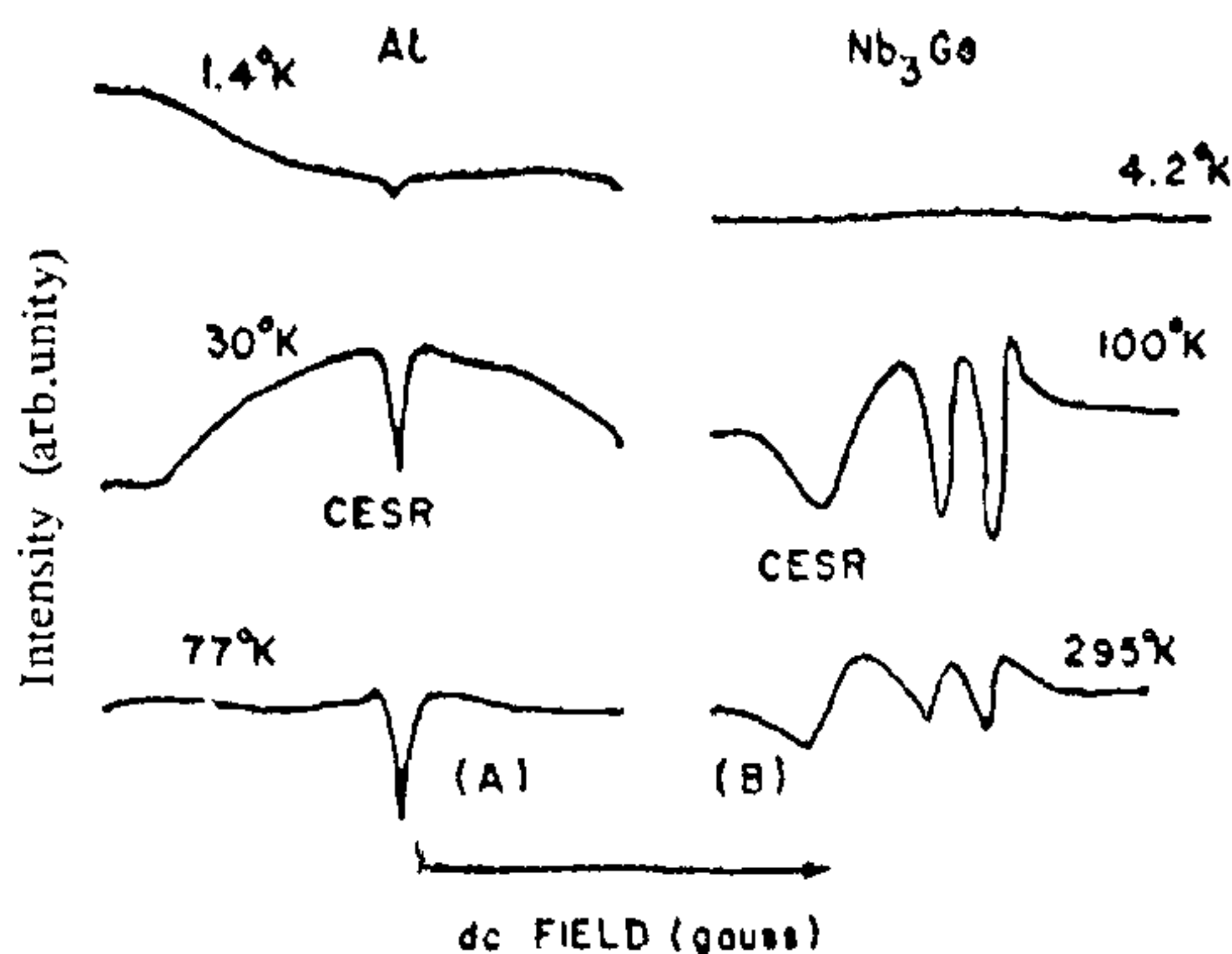


FIG. 1. CESR spectra at various temperatures for (A) Al and (B) Nb<sub>3</sub>Ge  $g$ -value for Al = 1.997  $g$ -value for Nb<sub>3</sub>Ge = 2.022.