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# L.008 MAGNETOELASTIC INTERACTION AND PHONON DISPERSION IN RARE EARTH SYSTEMS.

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The theories which were used to explain the experimentally observed elastic properties of paramagnetic rare earth compounds[1] are restricted to a coupling of the rare earth ions to the homogeneous and inhomogeneous <u>strains</u> of the lattice[1,2]. The purpose of this work is to complete the present theory of magnetoelastic interactions in paramagnetic rare earth systems by including the coupling of the ions to <u>rotational</u> deformations of the lattice.[3]

We demonstrate that rotational invariance to leading order is ensured only if rotational interactions of first and second order in the displacements are included simultaneously in the spin-lattice Hamiltonian. The rotational second-order interactions yield effects which are as large as those of the linear rotational interaction. The reason for this is that the linear interaction contributes to the phonon dispersion only <u>quadratically</u>, whereas the bilinear interactions contribute already in <u>first</u> order (see Fig. 1 below). This statement holds also for the pure strain interactions. Furthermore we show that in an applied magnetic field the rotational interactions cause measurable changes of the phonon dispersion and the sound velocity even in cubic paramagnetic systems. These effects are found to be of the same order of magnitude as the corresponding strain effects and are qualitatively different from the latter. Quantitative predictions for the sound velocity in SmSb are given as an example.

The essential steps of our theory are the following: We expand the interaction of the rare earth ions with the electrostatic crystal field in powers of the displacements of the ions from their rest positions and retain all terms up to second order. Turning to a continuum description and requiring rotational invariance we obtain the following magnetoelastic interaction

$$V = \sum_m \left[ H^m_{Strain} + H^m_{Rotation} \right] , \qquad (1)$$

$$H^m_{Strain} = G_{\alpha\beta}(\underline{J}^m)\, E^m_{\alpha\beta} + \frac{1}{2} F_{\alpha\beta\gamma\delta}(\underline{J}^m)\, E^m_{\alpha\beta} E^m_{\gamma\delta} , \qquad (2)$$

$$H^m_{Rotation} = - V_{\alpha\beta}(\underline{J}^m) \left[ \omega^m_{\alpha\beta} + \frac{1}{2} ( \omega^m_{\alpha\gamma} \omega^m_{\gamma\beta} + \varepsilon^m_{\alpha\gamma} \omega^m_{\gamma\beta} - \varepsilon^m_{\beta\gamma} \omega^m_{\gamma\alpha} ) \right] + G_{\alpha\beta\gamma\delta}(\underline{J}^m)\, \varepsilon^m_{\alpha\beta} \omega^m_{\gamma\delta} + \frac{1}{2} V_{\alpha\beta\gamma\delta}(\underline{J}^m)\, \omega^m_{\alpha\beta} \omega^m_{\gamma\delta} . \qquad (3)$$

Here $E^m_{\alpha\beta}$ and $\varepsilon^m_{\alpha\beta}$ are the components of the finite and the infinitesimal strain tensors, respectively, at the position of the m-th ion, and $\omega^m_{\alpha\beta}$ is the antisymmetric part of the deformation tensor describing rotational deformations of the lattice. All tensor operators in Eqs. (2) and (3) are sixth-degree polynomials of the spin operators $J^m_x$, $J^m_y$, $J^m_z$ of the m-th ion and have the appropriate symmetry of the lattice.

We calculate the phonon Greens function in the random phase approximation by means of the diagrammatic equation shown in Fig. 1.

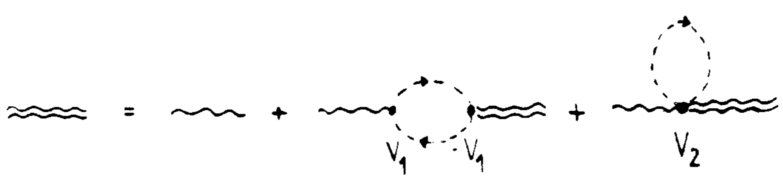


Fig. 1. Diagrammatic representation of the phonon propagator drawn as a double wavy line. The bare phonon propagator is represented by a single wavy line. The phonons interact with the rare earth ions via the linear interaction $V_1$ and the second-order interaction $V_2$ as contained in Eqs. (2) and (3). The dashed lines indicate the 2J + 1 ionic states split by the crystalline field and by an external magnetic field.



From this it is straightforward to obtain the relation for the phonon dispersion.[4]

Applying our resulting equation to the cubic paramagnetic phase of SmSb and using recent data for this material[1] we are able to predict quantitatively the rotational effects in an experiment analogous to that of Melcher[5] for $MnF_2$. We find a difference between the relative changes of the transverse sound velocities in the x- and the z-direction of the order of $10^{-4}$ in the presence of a magnetic field $H_z$ = 50 kG. The field-dependent change of the sound velocity due to the strain interaction is found to be of the same order of magnitude.

It is discussed how the rotational interactions affect possible structural phase transitions in rare earth compounds.

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