THE INFLUENCE OF SPIN-LATTICE COUPLING ON AN EXCITATION IN TRIANGULAR LATTICE HEISENBERG ANTIFERROMAGNET (TLHA). II. EXCITATION COUPLING WAVES

M.N. ABDULLAEV, N.F. ABDULLAEV, K.M. SULTANOV

Institute of Physics of Academy of Sciences of Aserbaijan, 370143, Baku, H. Javid prosp., 33

In the first part of the present paper an excitation of spin waves in antiferromagnetics with triangular lattice is studied without taking into account the spin lattice coupling. The first part is devoted to the calculation of the spin wave energy spectrum [1]. An analytical expression for the spin wave energy spectrum with $k_s \neq 0$ has been round.

In the second part we report the formation of magnetoelastic bound waves by spin lattice coupling in TLHA. For ordinary two-sublattice antiferromagnetics the excitation of the spin waves with spin lattice coupling was considered in the work [2]. Therefore it is interesting to discuss such a type of interaction for the triangular lattice.

Spin-phonon interaction

Next we consider the influence of the spin-lattice interaction on the excitation energy of the spin wave in the 120°structure. The interaction Hamiltonian for this system is given by [3]

are upon-like, while L. and E. are the complete model

or pool of the solutions (7). Next if we restrict ourselve

$$H_{int} = \sum_{\substack{a=1,2\\b=2,3\\a\neq b}} \sum_{\substack{j_a,j_b\\a\neq b}} \frac{\partial J(R_{j_aj_b})}{\partial R_{j_aj_b}} \left(\Delta \vec{R}_{j_a} - \Delta \vec{R}_{j_b}\right) \vec{S}_{j_b} \vec{S}_{j_b} , (1)$$

where $\Delta \vec{R}_j$ is the displacement vector of the j atom from its equilibrium position. It can be expressed in terms of the creation and annihilation operators by the formula

$$\Delta \vec{R}_{j} = \frac{1}{\sqrt{N/3}} \sum_{q} \vec{e} \left(q\right) \left(d_{q} + d_{-q}^{*}\right) e^{i \vec{q} \vec{\theta}_{j}}, \quad (2)$$

Here d_{q}^{*} and d_{q} are the phonon operators for the vibration of the lattice point $j_*\tilde{e}(q)$ the polarization unit vector of the wave with the vector \tilde{q} . We assume that the lattice variable $\Delta \tilde{R}_{i}$ is described by the Einstein model.

Here the conversion of the spin operators to the magnon operators (via the Holstein-Primakoff transformation) is defined in a manner analogous to that in the first part of the paper.

As a result we obtain the following form for the interaction Hamiltonian

$$H_{int} = -\sum_{qk} \left\{ A_{12}(q) \left(d_q + d_{-q}^* \right) \left(a_k + a_{-k}^* \right) + A_{23}(q) \left(d_q + d_{-q}^* \right) \left(b_k + b_{-k}^* \right) + A_{23}(q) \left(d_q + d_{-q}^* \right) \left(b_k + c_{-k}^* \right) \delta(k+q) \right\}$$
(3)

Here the functions $A_{12}(q)$, $A_{13}(q)$ and $A_{23}(q)$ are given by

$$\begin{split} A_{12}(q) &= \left[\frac{s^2 \hbar}{6 M \omega_q} \right]^{3/2} \left(\vec{e} \cdot (q) \left[\frac{\partial U(\Delta_1)}{\partial R_{\Delta_1}} (1 - e^{-i \vec{\phi} \vec{a}_1}) - \right. \right. \\ &\left. - \sum_{A_1} \frac{\partial U(\Delta_2)}{\partial R_{A_2}} (1 - e^{-i \vec{\phi} \vec{a}_2}) \right] \right) \\ A_{13}(q) &= \left[\frac{s^2 \hbar}{6 M \omega_q} \right]^{3/2} \left(\vec{e} \cdot (q) \left[\sum_{A_1} \frac{\partial U(\Delta_2)}{\partial R_{\Delta_2}} (e^{i \vec{\phi} \vec{a}_1} - 1) - \right. \right. \\ &\left. - \sum_{A_2} \frac{\partial U(\Delta_3)}{\partial R_{\Delta_2}} (1 - e^{-i \vec{\phi} \vec{a}_2}) \right] \right) \\ A_{23}(q) &= \left[\frac{s^2 \hbar}{6 M \omega_q} \right]^{3/2} \left(\vec{e} \cdot (q) \left[\frac{\partial U(\Delta_2)}{\partial R_{\Delta_2}} (e^{i \vec{\phi} \vec{a}_1} - 1) - \right. \right. \\ &\left. - \sum_{A_3} \frac{\partial U(\Delta_3)}{\partial R_{A_3}} (e^{i \vec{\phi} \vec{a}_2} - 1) \right] \right) \end{split}$$

where
$$\dot{a}_1=\vec{R}_1-\vec{R}_2$$
; $\dot{a}_2=\vec{R}_1-\vec{R}_3$; $\dot{a}_3=\vec{R}_2-\vec{R}_3$.

Note that in the expression (3) the terms higher than quadratic with respect to magnon and phonon operators were neglected because they to play a role in the relaxation.

We now derive Green functions and reduce them calculation analogue to that of the Green functions (9) in first part of the paper. In this case we can easily obtain the equations of motion for the Green functions analogous to unperturbed system (9), but with H_2 replaced by

$$H = H_2 + H_{ch} + H_{int}$$
 (4)

Here Hon is the energy operator of a phonon.

The resulting equations for the Green functions are

$$\begin{split} &-EG_{k}^{I}=S+\varepsilon_{1}G_{k}^{II}+(M_{12}^{*}-M_{12}^{*})\underline{\lambda}_{k}G_{k}^{II}+(M_{13}^{*}-M_{13}^{*})\lambda_{k}G_{k}^{II}\\ &-EG_{k}^{II}=\varepsilon_{1}G_{k}^{I}+(M_{12}^{*}+M_{12}^{*})\underline{\lambda}_{k}G_{k}^{III}+(M_{13}^{*}+M_{13}^{*})\lambda_{k}G_{k}^{I}-\\ &-\lambda_{12}H_{k}^{I}\\ &-EG_{k}^{III}=(\varepsilon_{22}-2D_{12})G_{k}^{IV}+(M_{32}^{*}-M_{42}^{*})\lambda_{k}G_{k}^{II}+\\ &+(M_{23}^{*}-M_{23}^{*})\underline{\lambda}_{k}G_{k}^{II} \end{split}$$

derived. We note that II, and II, colorides with the modes

$$-EG_k^{IV} = (\varepsilon_{22} + 2D_{12}) G_k^{III} + (M_{12}^* + M_{12}^-) \lambda_k G_k^I +$$
 are spin-like, while E_{*c}^2 and E_{*c}^2 are the coupled mode between spin and phonons. We note that $\eta^*(R_k)$ will be very small for small k_k (so $EG_k^V = (\varepsilon_{33} + 2D_{13}) G_k^{VI} + (M_{23}^* - M_{23}^*) \lambda_k G_k^{IV} +$ (3°)). Therefore we may use the small $\eta^2(R_k)$ approximation for root of the solutions (7). Next if we restrict ourselves the assumption that the $H_{13}^* + H_{13}^* + H_{13}^* + H_{13}^* + H_{23}^* + H_{23}$

We note that in the system (5) the Green functions of the following type

$$H_{k}^{T} = \left\langle \left\langle \left(\left(d_{k} + d_{-k}^{*} \right) / S_{k}^{y} \right) \right\rangle$$

$$H_{k}^{TI} = \left\langle \left\langle \left(\left(d_{k} - d_{-k}^{+} \right) / S_{k}^{y} \right) \right\rangle$$
(6)

yield results of Hamiltonian (3). We can not find the exact solution of the system (5) as in (9) for the arbitrary value of k. Therefore we show to perform an approximation with respect to k. We also note that the solution of the system (9) can be found for two values of k=0 ; k, while that of (5) only for one value of k=k. As may be seen from (3') at k=0 the interaction Hamiltonian vanishes.

Therefore it is not interesting to discuss such a type of approximate solution of the system (5). Using the lie of the spins in figure we carry out the sums with respect to A; and Δ_2 in expression (3') and we define the equally terms which cancel each other because opposite sings (in result A12=0). Next if we use the small value of wave number k_x we can deduce that $A_{2,2} = A_{2,3} = 0$ (1) restricted with a last section of

To simplify the calculations during the solution of system (5) we replace the Green functions in the equations with even numbers by those in the equations with odd numbers. These solutions are analogous to those which we used to evaluate the dispersion dependences of the spin wave in (10). Thus the solutions of the system (5) have the following form

$$\begin{aligned}
& \left\{ E^4 - \gamma_1^2(k_x) E^2 + \gamma_2^2(k_x) \right\} \times \\
& \times \left\{ E^4 - \left[\omega_{1S}^2(k_x) + (\hbar \omega(k_x))^2 \right] E^2 + \right. \\
& + \left[\omega_{1S}(k_x) \omega(k_x) \hbar \right]^2 - \eta^2(k_x) \right\} = 0
\end{aligned}$$
(7)

where $\eta^2(k_x) = 2A_{23} \left[2JSZ(1-\lambda_{k_x}) + \frac{DS}{2} \right]$ the other terms defined by the expression (11).

As a result, four different modes E_{2c}^2 ; E_2^2 and E_3^2 are derived. We note that E_2^2 and E_3^2 coincides with the modes which are obtained from the solutions of the second multiplier in (10) of the reference [1]. It is seen, that these modes are spin-like, while E_{+c}^2 and E_{-c}^2 are the coupled modes

We note that $\eta^{\alpha}(k_{x})$ will be very small for small k_{x} (see $EG_k^V = (\varepsilon_{33} + 2D_{13})G_k^{VZ} + (M_{23}^+ - M_{23}^+)\lambda_k^*G_k^{TV} + \frac{1}{2}G_k^{TV} + \frac{1}{2}$ for root of the solutions (7). Next if we restrict ourselves to

$$\frac{\eta^2(k_x)}{\omega_{15}^2(k_x) - (\hbar\omega(k_x))^2} << 1$$
 (8)

then, from the second multiplier of the equation (7) we get

$$E_{+c}^{2} \approx \omega_{1S}^{2}(k_{x}) + \frac{2\eta^{2}(k_{x})}{\omega_{1S}^{2}(k_{x}) - (\hbar\omega(k_{x}))^{2}};$$

$$E_{-c}^{2} \approx \left[\hbar\omega(k_{x})\right]^{2} - \frac{2\eta^{2}(k_{x})}{\omega_{1S}^{2}(k_{x}) - (\hbar\omega(k_{x}))^{2}};$$
(9)

In figure it is shown the schematic displacement dispersion curves of the spin and elastic waves because of the spinlattice interaction.

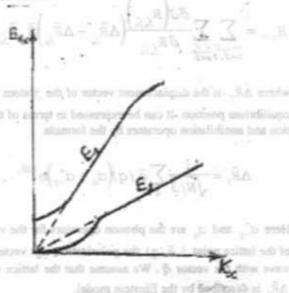


Fig. The dispersion curves of the spin and elastic waves. Here the conversion of the spin operate

From these curves it is seen that the interaction plays the essential role for E_{*c}^2 and E_{*c}^2 at certain value of k_s .

eventure (via the Holotein-Primakoff transformat

In this figure the dashed lines illustrate the dispersion relation for spin and elastic waves.

We note that
$$E_1^2(k_x = 0) = \omega_{1S}^2(0) = \frac{DS}{2}(33SZ - DS)$$

are the minimization values of $\omega_{18}^2(k_x)$ and shown in figure as the energy gap, while the maximization that following

are to be determined in
$$arccos \frac{1}{2} \left(1 - \frac{3}{2} \frac{D}{JZ} \right) \le ak_x \le \frac{2\pi}{3}$$

THE INFLUENCE OF SPIN-LATTICE COUPLING ON AN EXCITATION IN TRIANGULAR LATTICE HEISENBERG

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M.N. Abdullayev, N.G. Abdullayev, K.M. Sultanov

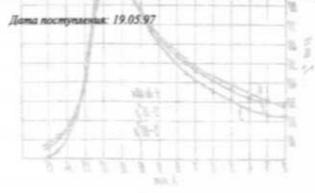
OEYRİ KOLLENİAR ÜÇ YARIMQƏFƏSLİ HEYZENBERQ ANTİFERROMQNİTLƏRDƏ ELEMENTAR OYANMALARDA SPÎN-FONON QARŞILIQLI TƏ'SİRİ. II. ƏLAQƏLİ DALĞALARIN OYANMASI

оти, вликтурущим и монтрукционные запирамым формирамизации от Baxılan maqnit sistemlerində əlaqəli spin-elastiki dalğaların oyanmasına baxılmış və onlar üçün enerji spektri hesablanmışdır. Hemçinin enerji zolağının aşağı ve yuxarı serheddi müəyyenləşdirilmişdir. İşin birinci hissesində olduğu kimi bu hissedə də hesablama iki zamanlı Qrin funksiyası üsulu ilə aparılmışdır.

М.Н. Абдуллаев, Н.Г. Абдуллаев, К.М. Султанов от пользования

СПИН-ФОНОННОЕ ВЗАИМОДЕЙСТВИЕ В НЕКОЛЛИНЕАРНЫХ ТРЕХПОДРЕШЕТОЧНЫХ ГЕЙЗЕНБЕРГОВСКИХ АНТИФЕРРОМАГНЕТИКАХ. ІІ. ВОЗБУЖДЕНИЕ СВЯЗАННЫХ ВОЛН

В работе рассмотрено возбуждение связанных спин-упругих воли и вычислен их энергетический спектр. Определены нижняя и верхиях границы энергетической щели. Для вычислений применен метод двухиременных функций Грина.



Как выдво за ресунка, смешения менличия сполост за вістомуюю завачемам з мунтанцильном повчания ви артино итакай басевованором в изака и гивали Выхонется вермечаестами уменализми фотоутстви-

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На забание 1 представлены зависнности обчаружеприменения водинатичной мунитантичности фоторозичени рев сантых при 77 К от балосися такия излучений.

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