LOCALIZED MAGNETOSTATIC MODES IN MAGNETIC SUPERLATTICES

R.T. TAGIYEVA

Institute of Physics of Academy of Sciences of Azerbaijan
H. Javid, av.33, Baku, 370143

The general dispersion equations for localized magnetostatic modes in the infinite magnetic superlattices with layered defects are derived in the framework of the transfer-matrix formalism. The layers are assumed to be film planes and parallel to the film planes and parallel to one another.

It is known that localized spin-wave modes as well as bulk spin waves. may occur in an ordered magnetic super lattices. when the magnetic system does not possess full translational symmetry e.g., due to surface or due to impurities (or other lattice defects) in super lattices. There are many reviews or the properties of surface spin waves in magnetic super lattices. There is also literature on localized spin in SL [1-5] .

Our motivation here is to present some calculation for localized magnetostatic waves in the presence of defect layer. In this paper we consider the infinite superlattice with the elementary unit consisting of two ferromagnetic layers of thicknesses d_j (j=1,2) with the spontaneous magnetisation parallel to the static magnetic field H_0 and parallel to the film planes. Let the axes z and x of the coordinate system be directed along magnetic field and normal to the film planes, respectively.

In a superlattice containing a defect layer, in addition to the bulk magnetostatic modes exist another magnetostatic mode localized by this defect layer. Magnetostatic waves propagates free!y over the defect layer and damps in the perpendicular direction on either side of the defect region. The region $0<x<d_0$ occur defect layers with magnetisation M_0. The general solution of equation for scalar potential φ (defined by $h=grad\ \varphi$, with h being the magnetic field) can be written in the form [6]:

$$\Phi_{m,j}(x) = A^{(+)}_{m,j}\exp\left\{\alpha^{(j)}\left[x-(m-1)L\right]\right\} + A^{(-)}_{m,j}\exp\left\{-\alpha^{(j)}\left[x-(m-1)L\right]\right\} \qquad (1)$$

and

$$\Phi^{(0)}_{(x)} = B^{(+)}\exp(\alpha^{(0)}x) + B^{(-)}\exp(-\alpha^{(0)}x) \qquad (2)$$

in defect layer.

Here
$$\alpha^{(0)^2} = \left(\mu^{(0)}_{\perp}k^2_{||y} + k^2_{||z}\right)\Big/\mu^{(0)}_{\perp} \qquad (3)$$

$$\alpha^{(j)^2} = \left(\mu^{(j)}_{\perp}k^2_{||y} + k^2_{||z}\right)\Big/\mu^{(j)}_{\perp} \qquad (4)$$

$$j=1,2$$

$$\Omega_0 = g\mu_o\gamma_o(H_o+H_a) \qquad (5)$$

$$\Omega_m = g\mu_o\gamma_o M_o$$

$$\mu_{\perp} = 1 + \Omega_0\Omega_m\Big/\left(\Omega_0^2-\omega^2\right) \qquad (6)$$

$$\mu_x = -\Omega_m\omega\Big/\left(\Omega_0^2-\omega^2\right) \qquad (7)$$

Here Ω_0 is the frequency of the uniform bulk: mod; g,μ_0 and H_a denote the Lande factor, magnetic permeability or the vacuum and uniaxial magnetic anisotropy field, respectively γ_0 is defined $\gamma_o=e/2m$ (e and m are the electron charge and electron mass .respectively. M_0 is the spontaneous magnetization of the corresponding material. Applying the boundary conditions for the tangential component of h and normal component of $\vec{b} = \mu_0\vec{\mu}\vec{h}$ to the left and right boundaries of the defect layer, one obtains transfer matrix R across the defect:

$$\begin{bmatrix}\tilde{A}^{(+)}_{1,1}\\ \tilde{A}^{(-)}_{1,1}\end{bmatrix} = R_2 * R_1\begin{bmatrix}A^{(+)}_{1,1}\\ A^{(-)}_{1,1}\end{bmatrix} = R\begin{bmatrix}A^{(+)}_{1,1}\\ A^{(-)}_{1,1}\end{bmatrix} \qquad (8)$$

From the condition or solvability of equation (8) derives the general dispersion relation for localized magnetostatic waves in superlattices with defect:

$$W_1(R_{11}+R_{12}W_2) - R_{21} - R_{22}W_1 = 0 \qquad (9)$$

The expression for the elements of the transfer matrix R are given, in the Appendix.

Here $W_1(L)$ and $W_2(L)$ are defined by equation

$$W_1 = A^{(-)}_{1,1}\Big/A^{(+)}_{1,1} = \left(\lambda_1 - \left(T^{-1}\right)_{11}\right)\Big/\left(T^{-1}\right)_{12} \qquad (10)$$

$$W_2 = \tilde{A}^{(-)}_{1,1}\Big/\tilde{A}^{(+)}_{1,1} = \left(\lambda_2 - T_{11}\right)\Big/T_{12} \qquad (11)$$

Here T_{ij} are elements of the transfer matrix for SL, and λ are eigenvalues of transfer matrix. The modes which are localized at the defect can propagate region, where the eigenvalues of the matrix T have the form $\lambda_{\pm}=exp(\pm\beta L)$ with $\beta=k$ or $\beta=in/L+k\ (k\text{-}real)$, β is the decay parameter which fulfils the following equation

$$ch\,(\beta L)=1/2\,(T_{11}+T_{22}) \qquad (12)$$

Here L-period of SL. The expression for matrix elements T_{ij} are given in [7]. Equation (9), (10) and (11) determine the frequencies of magnetostatic modes localized at the defect. Eliminating β from (10) and (11) by using (12), one can obtain the relation between the frequencies of localized magnetostatic waves and the parameters of the defect layer. For numerical calculations we assume the parameters appropriate to $Fe\,(\mu_0 M_0^{(Fe)}=2.15T..g^{(Fe)}=2.15)$ and $Co\,(\mu_0 M_0^{(Co)}=1.76T..g^{(Co)}=2.17)$.

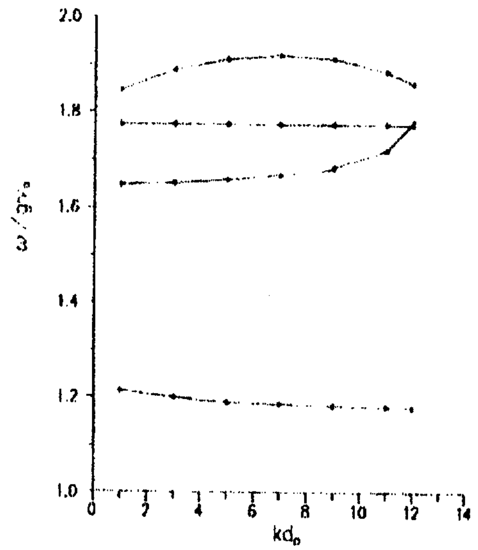

Fig.1. Frequencies of localized magnetostatic wave as function of the thickness of the defect layer. The following parameters have been used: $d_1/d_2=1,\ \mu_0 M_0=0,5T,\ \Omega_0/g\gamma_0=1T$.

The localized magnetos!atic waves in the magnetic SL are shown in figure 1 and 2 by curves. The numerical calculation are presented for the different parameters of the defect layer. In the general case there are four branches of localized waves. The lower branch is below the band of the bulk waves in SL (Fe-Co) and essentially depend on the parameters of defect. The upper branches exist in a restricted range of the frequencies between the bands *or* the bulk modes and above. The spectrum of the localized magnetostatic waves is reciprocal, $\omega(-k)=\omega(k)$.

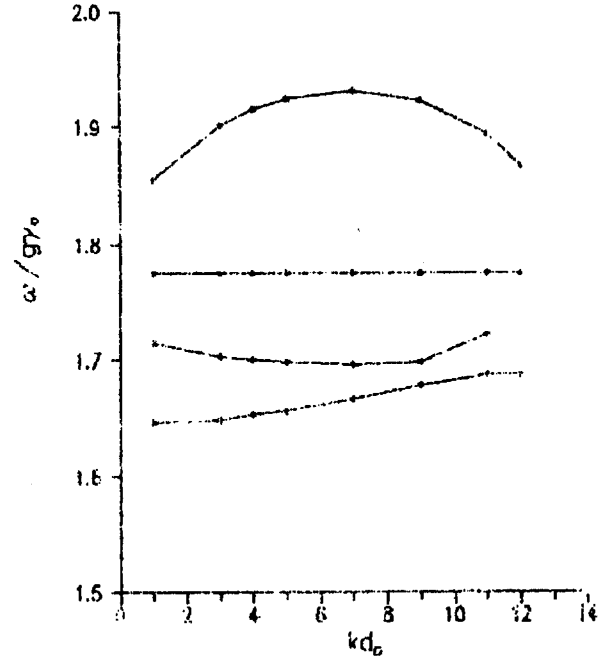

Fig.2. $\mu_0 M_0=0,5T,\ \Omega_0/g\gamma_0=1,5T$.

APPENDIX

The elements of the transfer matrix R has presented by the form:

$$R_{11(22)} = \frac{e^{\mp\alpha^{(1)}}d_0}{4\mu_\perp^{(0)}\alpha^{(0)}\mu_\perp^{(1)}\alpha^{(1)}}\Big\{\Big(\mu_\perp^{(1)}\alpha^{(1)} \pm \mu_\perp^{(0)}\alpha^{(0)} \pm \big(\mu_x^{(1)} - \mu_x^{(0)}\big)k_{||y}\Big)\times$$
$$\times\Big(\mu_\perp^{(0)}\alpha^{(0)} \pm \mu_\perp^{(1)}\alpha^{(1)} - \big(\mu_x^{(1)} - \mu_x^{(0)}\big)k_{||y}\Big)e^{\alpha^{(0)}d_0} + \Big(\mu_\perp^{(1)}\alpha^{(1)} \mp \mu_\perp^{(0)}\alpha^{(0)} \pm \big(\mu_x^{(1)} - \mu_x^{(0)}\big)k_{||y}\Big)\times$$
$$\times\Big(\mu_\perp^{(1)}\alpha^{(1)} \mp \mu^{(0)}\alpha^{(0)} + \big(\mu_x^{(1)} - \mu_x^{(0)}\big)k_{||y}\Big)e^{-\alpha^{(0)}d_0}\Big\}$$

$$R_{12(21)} = \frac{e^{\mp\alpha^{(1)}}d_0}{4\mu_\perp^{(0)}\alpha^{(0)}\mu_\perp^{(1)}\alpha^{(1)}}\Big\{\Big(\mu_\perp^{(1)}\alpha^{(1)} \pm \mu_\perp^{(0)}\alpha^{(0)} \pm \big(\mu_x^{(1)} - \mu_x^{(0)}\big)k_{||y}\Big)\times$$
$$\times\Big(\mu_\perp^{(0)}\alpha^{(0)} \mp \mu_\perp^{(1)}\alpha^{(1)} - \big(\mu_x^{(1)} - \mu_x^{(0)}\big)k_{||y}\Big)e^{\alpha^{(0)}d_0} + \Big(\mu_\perp^{(1)}\alpha^{(1)} \mp \mu_\perp^{(0)}\alpha^{(0)} \pm \big(\mu_x^{(1)} - \mu_x^{(0)}\big)k_{||y}\Big)\times$$
$$\times\Big(\mu_\perp^{(0)}\alpha^{(0)} \pm \mu_\perp^{(1)}\alpha^{(1)} + \big(\mu_x^{(1)} - \mu_x^{(0)}\big)k_{||y}\Big)e^{-\alpha^{(0)}d_0}\Big\}$$

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MAQNİT İFRATQƏFƏSDƏ LOKALLAŞMIŞ MAQNİTSTATİK DALĞALARIN YAYILMASI

Köçurmə matrisi metodu ilə defektli qeyri-məhdud maqnit ifratqəfəsdə lokallaşmış maqnitstatik dalğaların dispersiya tənliyi alınmışdır. Maqnitləşmə vektoru layların müstəvilərinə paralel götürülmüşdür.

Р.Т. Тагиева

ЛОКАЛИЗОВАННЫЕ МАГНИТОСТАТИЧЕСКИЕ ВОЛНЫ В МАГНИТНОЙ СВЕРХРЕШЕТКЕ

В рамках метода матрицы переноса получено дисперсионное уравнение для магнитостатических волн, локализованных в неограниченной магнитной сверхрешетке с дефектом. Предполагается, что вектор намагниченности лежит параллельно плоскости слоя и для всех слоев векторы намагниченности параллельны.

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