Degree of Sublattice Noncompensation of Antiferromagnet at the Antiferromagnet/Ferromagnet Interface

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A degree of sublattice noncompensation of antiferromagnet (DSNA) can play a crucial role in the designing of a diagonal-like and curvilinear geometry at interfaces of antiferromagnet (AFM) with other magnetic media because of the exchange interaction both between AFM sublattices and with neighboring material. We present a conceptually advanced theory which uses a variable DSNA to describe the behavior of spin waves (SWs) propagation through any designed AFM/FM interface. We propose the boundary conditions for any case of the DSNA. We demonstrate the dependency of transmittance, reflectance and corresponding phase shifts at the interface on the DSNA according to the reasonable SW wavelength.

Keywords: antiferromagnet, ferromagnet, interface, noncompensated sublattices, compensated sublattices

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Introduction. — The benefits of using antiferromagnets (AFMs) are well highlighted [1–7] but usually, antiferromagnets are considered not in full details, but in limited cases, namely, compensated (the AFM has no static magnetization at the interface) and noncompensated (the boundary of the AFM is magnetized) [8–11].

To describe the coupled dynamics of the staggered field in antiferromagnetic textures, AFMs are usually considered as spin systems in which neighboring spins compensate each other [12]. AFMs with the compensated spin moments on the atomic scale have the implementation within certain THz frequency range [13–15]. Antiferromagnetic spin oscillations induced by a spin current were investigated in such case [16]. Furthermore, the mechanism of switching the antiferromagnetic domains by the application of current pulses [17,18] is based on the field-like torque acting on the noncompensated spins at the interface [19,20]. Moreover, for the effective transmission of the spin current through thin dielectric AFM layers by a pair of externally excited evanescent AFM spin wave (SW) modes, it is assumed that the net magnetization of the AFM at the FM/AFM interface layer is partially noncompensated [21]. Lastly, the effective magnetic moment can be a complex arrangement of not fully compensated moments along the compensated structures [22]. Consideration of the aforementioned mechanisms based on the cases of compensated and noncompensated sublattices of the AFM requires perfectly flat interfaces.

While considering the cases with compensated and noncompensated sublattices, which are unlikely to form in not perfectly flat devices, the real rough interfaces with variable degrees of sublattice noncompensation are usually not considered or the degree of sublattice noncompensation is neglected. Therefore, only an approximation of the flat geometry based on flat interfaces with constant degrees of sublattice noncompensation can be implemented. However, we found out that taking into account a degree of sublattice noncompensation of AFM (DSNA) allows considering a diagonal-like and curvilinear geometry at interfaces with AFM. Interfaces with special structures that exhibit a DSNA can be manufactured in a variety of ways, such as change of surface roughness, ion implantation, vapor deposition or the introduction of other defects [23–27].

We present a theory to describe the propagation of SWs through any desired AFM/FM interface taking into account a variable DSNA. Thus, when we change the DSNA, it means that we, in fact, change a percentage of considered spins from the first and the second sublattice of the AFM on the boundary. We introduce an analytical theory of the SWs propagation through the AFM/FM interface depending on the DSNA in an exchange dominated regime and derive the boundary conditions on such interface.

Model and methods. — We extend and update the developed analytical model for the FM/AFM interface considered in Refs. [28,29] to investigate SWs propagation through the AFM/FM interface and ways to control it. In this letter, firstly, we describe the developed analytical theory for the scattering of exchange SWs on the AFM/FM interface of finite width sandwiched between AFM and FM semi-infinite thin films. By minimizing the total energy, we derive boundary conditions on the interface between AFM and FM [30,31]. We introduce a DSNA at the AFM/FM interface and obtain the complete relations between the phases and amplitudes of scattered SWs. We demonstrate the dependency of transmittance, reflectance and corresponding phase shifts on the DSNA.

Let us consider SWs propagation along the y-axis through an AFM/FM interface of two semi-infinite media, namely two-sublattice AFM and FM thin films, with a thickness of the interface δ, as shown in Fig. 1. The interface is parallel
to the \( x \)-\( z \) plane. Since AFM has two sublattices and FM has one, let us introduce static magnetizations, namely \( \mathbf{M}_{01}, \mathbf{M}_{02} \) and \( \mathbf{M}_0 \), respectively, within the interface and its surrounding, as shown in Fig. 1. The case when the static magnetizations \( \mathbf{M}_{01(02)} \) and \( \mathbf{M}_0 \) are parallel (antiparallel) everywhere in the system and the \( z \)-axis is considered. The saturation magnetizations are \( \mathbf{M}_{01(02)} \) and \( \mathbf{M}_0 \), where \( \mathbf{M}_{01(02)} = [0, 0, M_{01(02)}, \, \mathbf{M}_0 = [0, 0, M_{012}] \). The media is magnetized by the uniform static external magnetic field \( \mathbf{H} \) along the \( z \)-axis.

![Figure 1: Sketch of the system of two-sublattice AFM, the interface of finite thickness between AFM and FM, FM and magnetizations in each layer with the small perturbations of order parameters relative to the ground state. The normal to the interface \( \mathbf{n} \) is parallel to the \( y \)-axis.](image)

We treat the magnetization dynamics as small deviations of the magnetization vectors \( \mathbf{M}_{1(2)} \) and \( \mathbf{M} \) from the ground state, i.e. \( |\mathbf{m}_{1(2)}|^2 << |\mathbf{M}_{01(02)}|^2 \) and \( |\mathbf{m}|^2 << |\mathbf{M}_0|^2 \) in the form of \( \mathbf{M}_{1(2)} = \mathbf{M}_{01(02)} + \mathbf{m}_{1(2)} \) and \( \mathbf{M} = \mathbf{M}_0 + \mathbf{m} \), where \( \mathbf{m}_{01(2)} \) and \( \mathbf{m} \) denote the magnetization vector dynamical components of the first (second) sublattice of the AFM and FM, respectively.

Let us present the analytical theory of the SWs propagation through the AFM/FM interface in an exchange dominated regime. It is well known that the dynamics of magnetization in an effective magnetic field can be described by the Landau-Lifshitz equation (LLE) \( \partial \mathbf{M}_l / \partial t = g ( \mathbf{M}_l \times \mathbf{H}_{\text{eff},l} ) \), where \( g = 2 \mu_B / h \) is the gyromagnetic ratio for an isolated electron and \( \mathbf{H}_{\text{eff},l} \) stands for the effective magnetic field in each material that can be found from the functional derivative of the total energy density \( w \) with respect to each magnetization vector: \( \mathbf{H}_{\text{eff},l} = -\partial w / \partial \mathbf{M}_l \), where \( l \) indicates the three magnetic sublattices (the first and the second sublattice of AFM and the one of FM). Since we have stated the exchange dominated regime, let us note that within the interface only the exchange interaction and the coupling between AFM and FM have been taken into account [31–33] so that the exchange includes the antiferromagnetic coupling between two sublattices (the first term of Eq. (1)) and both ferromagnetic couplings between neighbors in each sublattice (this is the same as in the standard model for two FMs, namely the second and the third terms of Eq. (1)) [13].

As the coupling we postulate the exchange type of coupling characterized by energy density at the interface, i.e. the energy per unit area (the first three terms of Eq. (1)). The exchange energy density is \( 1/2 \alpha_l \left( \partial \mathbf{M}_l / \partial x_l \right)^2 \) (the last three terms of Eq. (1)) with the exchange interaction parameter \( \alpha_l = \alpha_{ex,l} \mathbf{M}_{0l}^2 \) (the inhomogeneous exchange constants [34]), where \( \alpha_{ex,l} \) is the exchange stiffness constant. Let us note that the exchange interaction parameter for first and second AFM sublattice is one — the last term of Eq. (1), and we have to consider the exchange between AFM sublattices as well — the fifth term of Eq. (1). Then the surface energy at the interface is \( W_{\text{int}} = \int_0^\delta W_{\text{int}} \, dy \), where the density of the energy at the interface \( w_{\text{int}} \) is following:

\[
W_{\text{int}} = \left\{ \alpha(y) / 2 \left( \left( \partial \mathbf{M}_1 / \partial y \right)^2 + \left( \partial \mathbf{M}_2 / \partial y \right)^2 \right) \right\} + \left\{ \alpha(y) / 2 \left( \left( \partial \mathbf{M}_1 / \partial y \right)^2 + \alpha_2(y) \left( \partial \mathbf{M}_1 / \partial y \right) \left( \partial \mathbf{M}_2 / \partial y \right) \right) \right\}
\]

where \( A(y) \) is the coupling parameter between AFM sublattices (the homogeneous exchange constant) which is related to the exchange stiffness constant and can be estimated through \( A \sim \alpha_{ex,l} \mathbf{M}_{0l}^2 / d^2 \), where \( d \) is the lattice constant of the AFM [34–36]; \( A_{l(2)}(y) \) is the coupling parameter between each sublattice of AFM and FM and significantly depends on the DSNA.

Therefore, considering the coupling limit, \( \delta \ll \lambda_{\text{SW}} \), we define the interface in terms of the average properties of surrounding materials, namely AFM and FM, taking into account the finite thickness of the interface [31]. The LLE is integrated over the thickness of the interface [0, \( \delta \)]. At the interface, the solution of the LLE satisfies the following boundary conditions for the amplitudes of the magnetization dynamical components, FM’s \( \mathbf{m} = [m_x, m_y, 0]^T \) and AFM’s \( \mathbf{m}_{0l(2)} = [m_{0l(2)x}, m_{0l(2)y}, 0]^T \) (for convenience expressed via the cyclic variables \( m_{0l(2)} = (m_{0l(2)x}, m_{0l(2)y}, m_{0l(2)z}) \) and the notations \( M_{0l}/M_{0l} = -1, \, M_0/M_{0l} = \gamma \) are used:

\[
\begin{align*}
A_{l(2)} m + \left( A_{l(2)} - \alpha_2 \frac{\partial}{\partial y} \right) m_{l(2)} &= 0 \\
A_{l(2)} m - \left( A_{l(2)} - \alpha_2 \frac{\partial}{\partial y} \right) m_{l(2)} &= 0
\end{align*}
\]

(2)
The set of linearized boundary conditions Eq. (2) was obtained in the first approximation taking into account the magnetizations as sums of their static values and small dynamic perturbations.

Let us note that when \( A_2 = -A_1, \alpha_2 = -\alpha_1 \) and \( m_2 = -m_1 \), the linearized boundary conditions Eq. (2) at the AFM/FM interface become the well-known linearized boundary conditions at the FM/FM interface [31], which is reasonable.

**Interrelation of the AFM magnetization dynamical components.** — Proportionality of AFM dynamical components \( m_1 \) and \( m_2 \) is obtained by solving two coupled LLEs for every designed boundary conditions at the FM/FM interface [31]. Let us include to the effective fields the standard contributions from exchange and anisotropy, together with external field and magnetic dipole interaction. Then, by (i) generating the Fourier transform of the equations and expressing the Fourier components of the deviations of the magnetic moments through the Fourier component of the alternating magnetic field, (ii) solving the set of linearized LLEs for every magnetization of the two sublattices of AFM [37] and (iii) considering \( M_{\alpha, z} = M \) and \( M_{\alpha, z} = -M \) we define an interrelation between \( m_1 \) and \( m_2 \) as the following:

\[
m_2 = -\sigma(\omega)m_1,
\]

where \( \sigma(\omega) \) is the proportionality factor of AFM dynamics:

\[
\sigma(\omega) = \frac{(\Omega - \Omega) (\Omega - \Omega) - \omega^2 + \omega(\Omega + \Omega - 2\Omega)}{(\Omega - \Omega)^2 - \omega^2},
\]

with the auxiliary functions

\[
\Omega = gM (A + \alpha k^2) \tag{4}
\]

\[
\Omega_{(1,2)} = gM (A + \alpha k^2 \pm H^0_{0}/M + \beta_1 - \beta_2). \tag{5}
\]

where \( H^0_{0} \) is the external magnetic field, \( k_1 \) is the wave vector of AFM, \( \beta_1 \) and \( \beta_2 \) are the magnetic anisotropy constants of AFM and \( \omega = 2\pi f \) with frequency \( f \).

**Degree of sublattice noncompensation of AFM.** — The set of equations in Eq. (2) has the solution with a non-zero amplitude of the transmitted SW only if the relations between the respective terms of the first and second equations in Eq. (2) are held, namely:

\[
A(1 - \sigma) - A_1 y = \mu (A(1 - \sigma) - \sigma A_2 y), \quad A_1 = \mu A_2 \\
(\alpha_1 - \sigma \alpha_2) = \mu (\alpha_2 - \sigma \alpha_1), \text{ keeping in mind the interrelation of AFM dynamics (Eq. (3))}.
\]

Otherwise, the SWs are fully reflected. Let us introduce the DSNA \( \mu \) as

\[
\mu = (\alpha_1 - \alpha_2 \sigma)/(\alpha_2 - \alpha_1 \sigma); \tag{6}
\]

the coupling parameters between each sublattice of AFM and FM \( A_{(1,2)} \) are defined through \( A \) depending on the DSNA as

\[
A_1(\mu) = A(1 - \mu)/\gamma, \tag{7}
\]

\[
A_2(\mu) = A(\mu)/\mu, \tag{8}
\]

since the influence of each sublattice is defined according to the DNSA as \( A_1 = \mu A_2 \).

Furthermore, the boundary conditions for any designed boundary should be reconsidered taking into account Eq. (3) and Eq. (8) so that the linearized boundary conditions (Eq. (2)) will include only two equations and can be rewritten as follows:

\[
\begin{aligned}
A_1(\mu)m - \left(\gamma A_1(\mu) - (1-\sigma)A + (\alpha_1 - \alpha_2 \sigma) \frac{\partial}{\partial y}\right) m_1 &= 0 \\
(1-\mu)A_2(\mu) + \gamma \alpha \frac{\partial}{\partial y} m - \gamma (\sigma - \mu) A_1(\mu)m_1 &= 0
\end{aligned}
\]

\[
(9)
\]
Let us analyze compensated and noncompensated cases separately. In the compensated case (see the grey "compensated case" of the Flat geometry in Fig. 2(a)) the DSNA $\mu = 1$ since $A_1 = A_2$ and, according to Eq. (7), the coupling parameters between each sublattice of AFM and FM $A_{k(2)}$ do not have an impact and are equal to zero. Due to the introduction of the DSNA, the reason for neglecting the coupling parameters is well elucidated. In the noncompensated case, two options can be observed: first – when the first AFM sublattice approaches the boundary (see the red "noncompensated case" of the Flat geometry in Fig. 2(a)) so that the DSNA $\mu \rightarrow \infty$ since $A_2 = 0$; second – when the second AFM sublattice approaches to the boundary (see the blue "noncompensated case" of the Flat geometry in Fig. 2(a)) so that the DSNA $\mu \rightarrow 0$ since $A_1 = 0$. By varying the DSNA, any flat case can be considered (see the green "other case" of the Flat geometry in Fig. 2(a)) and any other case can be designed (see the Curvilinear geometry in Fig. 2(b)).

Propagating of SWs through the AFM/FM interface. — We are looking for a solution in which the incident and reflected circularly polarized SWs in AFM (which must be considered for every AFM sublattice) and transmitted SWs in FM are monochromatic plane waves $m(r,t) = m(r)\exp(i\omega t)$ with dynamical components of the magnetization vectors defined as follows:

$$m_{(2)} = I_{(2)}\exp(ik_{A1}y) + r_{(2)}\exp(-ik_{A1}y)$$

$$m = t\exp(ik_{AP}y)$$

where $k_p$ is a wave vector of FM, $I_{(2)}$ is an incident wave amplitude onto the first (second) AFM sublattice, $r_{(2)}$ and $t$ are the complex amplitudes of the reflected wave from first (second) AFM sublattice and transmitted wave into FM, namely $R_{(2)} \exp \varphi_{R_{(2)}}$ and $T \exp \varphi_{T}$, respectively, with the amplitudes $R_{(2)}$, $T$ and phase shifts $\varphi_{R_{(2)}}$, $\varphi_{T}$, respectively. The formulation of the problem has a stationary state so the explicit dependence on time can be neglected.

Let us note that with respect to Eq. (3) the interrelations between amplitudes and phase shifts of the first and second AFM sublattices are defined as $I_1 = -\sigma I_1$, $R_1 = -\sigma R_1$ and $\varphi_R = \varphi_{R_1} - \varphi_R$, respectively. Thus, using the boundary conditions (Eq. (2)), the complex amplitudes of SWs are:

$$r_1 = -\frac{I_1(p(yA_2 - (1 - \sigma)A_i) + ik_{A1})}{p(yA_2 - (1 - \sigma)A) - i\mu k_{A1}},$$

$$t = \frac{2iI_1(\sigma - \mu)k_{A1}}{p(yA_2 - (1 - \sigma)A) - i\mu k_{A1}} ,$$

where $p$ and $q$ are auxiliary functions, namely

$$p = \frac{\gamma A_2 - (\mu - 1)(1 - \sigma)A}{\gamma(yA_2 - (1 - \sigma)A)(\alpha_i - \alpha_A) - i\alpha\mu k_{A1}},$$

$$q = \frac{\mu - 1}{\gamma} - i\frac{\alpha\mu k_{A1}}{A_1} .$$

To consider reflectance $R_1^2$, transmittance $T^2$, and corresponding phase shifts $\varphi_R$ and $\varphi_T$, we have to find $\text{abs}(r_1^2)$, $\text{abs}(t^2)$, $\arg(r_1)$ and $\arg(t)$, respectively, taking into account Eqs. (11)–(14).

To determine the spectrum of SWs in AFM and FM we use the well-known dispersion relations for AFM (taking into account the fact that the AFM has anisotropy of the "easy axis" $(\beta_1 - \beta_2) > 0$ and the AFM magnetic moment is small) and FM (taking into account normal incidence) [37], respectively:

$$\omega_\pm(k_A) = g \left[ 2A(\alpha_1 - \alpha_A)M_Ak_A^2 + H_0 \right]^{1/2} \pm gH_0^{\pm} ,$$

$$\omega(k_f) = g [ 2\alpha M_Ak_f^2 + M_f\beta + H_0^{\pm} ] ,$$

where $H_i = M_A\sqrt{2A(\beta_1 - \beta_2)}$ is anisotropy field of AFM, $\beta$ is anisotropy constant of FM, and $\omega$ is equal to $2\pi f$ with frequency $f$. In contrast to FM, AFM has not one but two branches of SWs (the number of branches is equal to the number of sublattices), and in the region of large wave vectors, both frequencies of SWs are proportional to the wave vector.

The directional energy flux density. — A general idea of the flow of mechanical energy in space was first introduced by N. A. Umov for elastic media about 1.5 centuries ago. The concept of electromagnetic energy flux density was developed by D. G. Poynting ten years later and is well known as the Poynting vector, which is used for SWs as well [37]. The concept claims that the normal component of the energy flux density vector – the Poynting vector – is continuous at the boundary between two media. Since in this letter we consider two-sublattice AFM, we have introduced the proportionality factor of AFM dynamics (Eq. (3)) and we have to define the additional term $\zeta$ for the continuity of the normal component of the Poynting vector at the interface. Thus, for the case of the AFM/FM interface taking into account the interrelation of Eq. (3) and dynamical components of the magnetization vectors (Eq. (10)) we have calculated the Poynting vector so that the concept can be written as follows:

$$R_1^2 + \zeta T^2 = I_1^2 , \zeta = \frac{\alpha k_{f}}{k_{f}(\sigma_f(1 + \sigma_f) - 2\sigma_A)}/$$

where the incident and reflected SW amplitudes from the second AFM sublattice are expressed as $I(R)_2 = -\sigma I(R)_1$ and included in Eq. (17).
Results and Discussion. — Let us assume the AFM/FM interface as NiO/CoFeB, then \( M = 0.84 \cdot 10^3 \) G and \( M_0 = 1.2 \cdot 10^3 \) G are the saturation magnetizations, \( \alpha_{\text{ext},1} = 5 \cdot 10^{-8} \) erg-cm\(^2\), \( \alpha_{\text{ext},2} = 2 \cdot 10^{-8} \) erg-cm\(^2\) and \( \alpha_{\text{ext}} = 5 \cdot 10^{-6} \) erg-cm\(^2\) are exchange stiffness constants, and the lattice constant of NiO \( d = 4.2 \cdot 10^{-8} \) cm [35]. Let us assume the external magnetic field \( H^{(e)}_0 = 5 \) kOe, the anisotropy field \( H^i = 3 \) kOe, the incident wave amplitude \( I_i = 1 \) and anisotropy constant of FM \( \beta = 0 \).

According to Eqs. (15)–(16), we have to take into account an activation frequency \( f_{\text{act}} = g \left( H^{(e)}_0 + H^i \right) / 2\pi \) to activate all three branches, and in the case of the aforementioned parameters, the frequency is equal to 22.4 GHz.

![Fig. 3](image-url)

**FIG. 3.** (Color online) In panel (a), concordances between SW wavelengths of both AFM branches (solid and dashed grey lines, that indicate plus- and minus-branch, respectively) and FM branch which are obtained with respect to Eqs. (15) and (16). Panel (b) gives the corresponding SW wavelengths dependence on frequency (AFM plus- and minus-branch – solid and dashed grey lines, respectively, and FM branch – solid blue line). Thus, by choosing a frequency we define the wavelengths of SWs that propagate into FM.

To define the proper frequency range for SWs propagating in the AFM/FM system we determined the reasonable SW wavelengths of AFM \( \lambda_{\text{AFM}} = 2\pi/k_{\text{AFM}} \) and FM \( \lambda_{\text{FM}} = 2\pi/k_{\text{FM}} \) equating each branch of the AFM dispersion relations (Eq. (15)) to the FM dispersion relation (Eq. (16)).

Increasing the frequency to THz range, two branches of AFM are converging to each other and the wavelengths of SWs are decreasing, as shown in Fig. 3(b). With decreasing frequency, the difference between SW wavelengths of AFM branches rapidly increases and, after a certain value of frequency, the SW propagation only from one AFM branch to FM is possible (see Fig. 3(a)).

According to Eq. (6) the DSNA \( \mu \) depends on the proportionality factor of AFM dynamics \( \sigma \), while \( \sigma \) depends on the frequency \( f \) and magnetic parameters of AFM (see Eqs. (4)–(5)).

![Fig. 4](image-url)

**FIG. 4.** (Color online) Panel (a) shows the dependency of the DSNA \( \mu \) on the proportionality factor of AFM dynamics \( \sigma \), where \( \alpha_1 \) and \( \alpha_2 \) are the exchange stiffness constants of AFM. Panel (b) shows the dependency of the proportionality factor of AFM dynamics \( \sigma \) on frequency \( f \) for both branches of AFM (plus- and minus-branch – solid and dashed orange lines, respectively).

When the proportionality factor of AFM dynamics \( \sigma \) is smaller than \( \alpha_2 / \alpha_1 \), the DSNA \( \mu \) is positive; when \( \sigma \) is larger than \( \alpha_2 / \alpha_1 \), the DSNA \( \mu \) is negative; lastly, when \( \sigma \) is going to \( \alpha_2 / \alpha_1 \) from the left (right), \( \mu \) is going to \( +\infty \) (\( -\infty \)) as it is shown in Fig. 4(a).

According to Eq. (3), the magnetization vector dynamical components of AFM are parallel to each other when the proportionality factor of AFM dynamics \( \sigma \) is negative. In such case, SWs propagate only with high frequencies, as it is shown in Fig. 4(b) (taking into account the aforementioned parameters, the frequency is higher than 100 GHz). In case when the magnetization vector dynamical components of AFM are antiparallel to each other, the proportionality factor of AFM dynamics \( \sigma \) is positive, and SWs can propagate with low frequency, as it is shown in Fig. 4(b).

Reflectance and transmittance depend on the DSNA according to Eqs. (11)–(12) taking into account the auxiliary functions Eqs. (13)–(14) and the additional term \( \xi \) for the continuity of the normal component of the Poynting vector at the interface (Eq. (17)). Considering the interrelation between the DSNA \( \mu \) and both the proportionality factor of AFM dynamics \( \sigma \) and coupling parameter between the first sublattice of AFM and FM \( A_1 \) according to Eqs. (6) and (7), respectively, the dependency of reflectance and transmittance on the DSNA can be shown. Furthermore, the phase shift between the incident and reflected SW \( \varphi_r \) does not depend on the DSNA and is always equal to \( \pi \), whereas the phase shift between the incident and transmitted SW \( \varphi_t \).
is equal to 0, except for the range $\mu \in [\alpha_2/\alpha_1, 1]$, within which $\varphi_r = \pi$ for any branch of AFM dispersion relations independent of frequency.

![Graph](image)

FIG. 5. (Color online) Transmittance (black solid and dashed lines indicate plus- and minus-branch, respectively) and reflectance (red solid and dashed lines indicate plus- and minus-branch, respectively) as functions of the DSNA $\mu$ for three different frequencies, namely 23.9 GHz, 37 GHz and 44.1 GHz.

In the compensated case we observe the full reflection from the interface independent of frequency (see Fig. 5 when $\mu = 1$). Considering the minus-branch of AFM dispersion relation in the noncompensated case, the transmittance and the reflectance are rapidly converging to each other (see Fig. 5 dashed lines when $\mu \to 0$ or $\infty$). For the plus-branch of AFM dispersion relation the transmittance and the reflectance are rapidly converging to each other only when $\mu \to 1$, and when $\mu \to \infty$ they are converging to each other only if the frequency is increasing (see Fig. 5 solid lines when $\mu \to 0$ and $\infty$). On high frequencies (higher than 100 GHz with respect to the aforementioned parameters) the difference in the behavior of the dependency for each AFM dispersion relation branch becomes insignificant and eventually disappears. At lower frequencies, the dependency for reflectance and transmittance on the DSNA is significant, as shown in Fig. 5.

Conclusions. — In this letter, we presented a new concept that makes an essential step towards solving a critical problem of controlling the SWs propagation through interfaces of AFM with other magnetic media by means of introducing a new physical characteristic of the interface of finite thickness, namely a degree of sublattice noncompensation of antiferromagnet (DSNA).

It has been demonstrated that the SWs transmission from AFM to FM is made possible only with a specific design of the interface – when its parameters satisfy the ratios Eqs. (6)–(8). Otherwise, the SWs are completely reflected from the FM surface.

We expect that our model and its implications will make it possible to design and describe a complex geometry at AFM interfaces not only with flat real profiles that take into account the crucial contribution of DSNA in rough and diagonal-like interfaces, but also the curvilinear interfaces with the variable DSNA.

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