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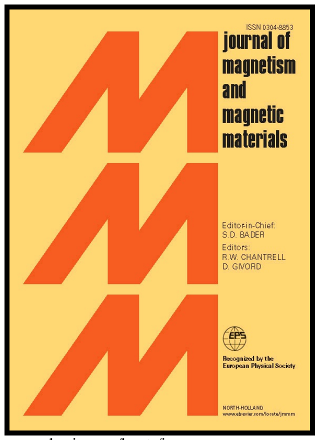

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Propagation of a magnetostatic surface spin wave through a finite magnonic crystal

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A new method of theoretical investigation of magnetostatic spin waves propagation in a 1D finite bi-component magnonic crystals is developed. The transmission and reflection coefficients for a magnonic crystal with low and high magnetization contrast are obtained. Using the method we define the boundaries of the infinite medium approximation. This method can be used for the investigation of non-periodic bi-component structures. Applications of said approach are presented.

I. INTRODUCTION

During the last decades one of the dynamically developing areas of magnetism is investigation of spin waves (SWs) propagation in magnonic crystals (MCs) [1, 2] which are magnetic analogues of photonic crystals [3, 4]. As an example of a MC one could consider a structure that consists of two different ferromagnetic layers alternating in space. In the dispersion relation of a wave propagating through such periodic magnetic structure there will appear band gaps specified by Braggs reflection condition $k = \frac{n}{\Lambda}$, where Λ is the period of a structure.

These band gaps, just like the photonic ones are dependant on materials and geometry of a specific sample but unlike their photonic analogues magnonic band gaps can be tuned by the external bias magnetic field [5–7], providing possibility for tunable devises such as delay lines or frequency filters [8, 9]. Experimental data also confirm band gaps formation in different one-dimensional MCs: formed by grooves on the surface of a ferromagnetic film [10, 11]; consistent of spaced ferromagnetic strips [12]; constructed of two different ferromagnetic strips alternating in space these MCs are also known as bi-component MCs [13–15].

These promising features have led to extensive investigation of MCs of different configurations. Early works investigated spin waves in one-dimensional MCs with small magnetization contrast, where $\frac{|M_{s1}-M_{s2}|}{M_{s1}} \ll 1$. The solution was obtained for backward volume spin waves and considered periodic exchange boundary conditions [2]. The dispersion relation exhibited clear band gaps which led to the continuation of research of different types of MCs with different configurations and geometries using various methods [5, 6, 16].

Remarkable results were achieved with the help of plane-wave method. This method is based on expansion of the exact solution into the set of eigenmodes and it was applied for different types of waves and border conditions. There are works investigating spin wave dynamics in 1-D [17], 2D [18, 19] and even 3D [20] MCs using this method. In our recent work [21] we investigate noreciprocity of the edge modes in one-dimensional MCs using the plane wave method to obtain dispersion relations of magnetostatic surface waves in two different types of 1D MCs. However this approach assumes MC to be infinite in the direction of propagation, which is not always viable for real structures.

Therefore with this work, as a continuation of our previous study [21], we aim to provide an analytical method to investigate magnetostatic surface spin wave dynamics in finite 1-D MCs with high contrast. We also consider the case of magnetostatic surface spin wave (MSSW), when external field lies in the plain of the film and the wave propagates in the perpendicular direction. As it was shown by Damon and Eshbach in 1961 [22] such wave exhibits non-reciprocal properties, waves propagating in the opposite direction propagate along the opposite sides of the film. That makes it difficult to fulfill boundary conditions at the interface between two ferromagnetic layers, without introducing some type of additional modes. To escape this predicament we consider the case of a thin film, where the thickness of the film is much smaller than a wavelength. We are also dealing with the case of dipole-dipole waves when exchange interaction is being neglected that approximation is justified for $k \ll \sqrt{2\pi M^2/A}$, (see for example [23]) where k is the wave vector, M is the saturation magnetization and A is the exchange constant of the material. However for each material with a specific saturation magnetization such dipole-dipole waves only exist in frequency window $\sqrt{\omega_H^2 + \omega_M\omega_H} < \omega < \omega_H + \frac{\omega_M}{2}$. That means that if these frequency windows do not overlap for materials composing the MC then the described method can not be used and one needs to take into account exchange interaction.

II. MATHEMATICAL MODEL

In this work we investigate propagation of magnetostatic surface spin waves in the 1D bi-component MC, see Fig. 1. Such crystal is a film with thickness d which consists of two alternating ferromagnetic stripes with different saturation magnetizations M_1 and M_2. The external magnetic field $\vec{H}_0$ as well as saturation magnetization of the stripes lie in the film plane, parallel to the z axis.

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