

Preface

The theoretical and experimental study of ferromagnetic resonance and spin waves – low lying excitations in magnetically ordered substances – has a long history. Experimental methods involving spin waves were used to determine fundamental parameters of magnetic materials, such as static magnetization, exchange constant, anisotropy constants, parameters of magnetic dissipation, etc. Also, spin waves excited at microwave frequencies have group and phase velocities that are much smaller than the velocity of regular electromagnetic waves of the same frequency and, in certain geometries, are non-reciprocal. These properties of spin waves make possible the development of miniaturized microwave signal processing devices, both reciprocal (filters, oscillators, delay lines) and non-reciprocal (isolators and circulators). An additional advantage of microwave signal processing devices based of spin waves is the possibility to tune the operational frequency of these devices by changing the external bias magnetic field applied to this device.

Recently the interest to the spin waves has been revived mostly due to the rapid developments of the novel fields of research, such as nanomagnetism and spintronics, and also due to the realization of the fact that spin waves have very interesting quantum properties. In many situations, spin waves could be (and should be) treated as magnetic quasiparticles – magnons. Magnons obey the Bose–Einstein statistics and can demonstrate interesting and unusual macroscopic quantum phenomena, such as Bose–Einstein condensation of parametrically pumped magnons at room temperature [1]. Magnons are also very interesting in spintronics as they are capable of carrying spin angular momentum (or pure spin current) and, therefore, can be used as possible carriers of spin current in magnetic dielectrics [2].

Another important development made possible by the progress in nanotechnology is the creation of artificial magnetic periodic structures with feature size of the order of the magnon wavelength – the so-called *magnonic crystals*. Similar to the well-known photonic crystals [3], magnonic crystals have designed-to-order band structure of the magnonic spectra and, therefore, novel dynamic properties that cannot be found in natural magnetic materials. The tuneability of magnonic crystals by an external field allows a *dynamic* creation of the magnetic periodicity in an artificial crystal with characteristic times comparable to the time of magnon propagation in

the crystal. This possibility results in the existence of the dynamic magnonic crystal with very unusual properties, allowing frequency transformation and reversal of magnon propagation in a purely linear system [4].

Nano-structuring of magnetic materials required significant modifications in the traditional theory of spin waves as the relative influence of the dipole–dipole and exchange interactions on the spectrum of magnons depends on the spatial size of the magnetic structure, the role of the exchange interaction being dominant for the nano-structured magnetic materials.

Experimental investigations of novel dynamic phenomena in magnetism require the development of new methods of probing and manipulation of magnetization dynamics in magnetically ordered substances. Ultrafast optical methods of experimental studies (see, e.g., [5]) made possible probing magnetization dynamics at a time scale that is shorter than the characteristic exchange time. At this time-scale, the length of the magnetization vector is not conserved and the traditional Landau–Lifshitz equation of motion for the magnetization is not valid.

All these factors lead to the formation of a new field of research – magnonics – that includes not only the traditional branches of spin wave research, but also the area of quantum properties of magnons, physics of artificial magnonic crystals, magnetic excitations at nano-scale and ultrafast magnetization dynamics.

The first major conference in the novel field of magnonics entitled “Magnonics: From Fundamentals to Applications” was held in Dresden, in August 2009, sponsored by the visitor program of the Max Plank Institute of Physics of Complex Systems (MPIPKS) [6]. The event had a great success and achieved its main aim – to form a community of magnonics researchers.

The 2nd edition of this conference entitled “International Workshop on Magnonics: From Fundamentals to Applications” was held in a resort city of Porto de Galinhas near Recife, the capital of the state of Pernambuco, Brazil in August 2011 and turned out to be equally successful. It demonstrated that magnonics is rapidly becoming a popular and mature field of research that brings together scientists and engineers interested in a wide variety of research topics ranging from fundamental magnonic properties to their application in the information technologies. The conference also demonstrated that magnonics is a convenient term allowing the unification of several novel branches of magnetization research, such as macroscopic quantum magnetic phenomena, probing and manipulation of magnetism with femtosecond light and polarized electrons, magnon spintronics, and physics of artificial magnonic crystals.

This book is based on the invited papers presented at the second conference on magnonics in Recife, Brazil in 2011 and reflects the current state-of-the-art in the field of magnonics. The volume contains 17 chapters separated into four topical sections.

The first section, devoted to the different magnonic modes and states, starts from the contribution by V.V. Naletov et al. where magnonic modes of magnetic nanopillar are experimentally identified using the method of magnetic resonance force microscopy. P.S. Keatley et al. also study magnonic modes in single nanomagnets and in pairs of dipolar coupled nanomagnets, but use the method of time-resolved

scanning Kerr microscopy. Chaotic magnonic states excited in active feedback ring containing macroscopic samples of ferrite magnetic films are studied in the contribution of A.M. Hagerstrom and M. Wu, while S. Rezende provides a theoretical overview of coherent magnonic states, including Bose–Einstein condensates of magnons.

The second section deals with the novel methods of probing and manipulation of magnons using femtosecond light and polarized electrons and starts with the contribution of A. Kiriljuk et al. that discusses the role of angular momentum in ultrafast magnetization dynamics. Probing of magnonic modes in arrays of magnetic antidotes using all-optical femtosecond laser experiments is discussed in the chapter by B. Lenk et al., while Kh. Zakeri and J. Kirschner report on the excitation of high wave-vector magnons in itinerant ferromagnets by means of polarized electron scattering experiments. The role of micromagnetic simulations and numerical solvers based on atomistic spin models in the theoretical understanding of ultrafast magnetization dynamics and interactions of magnons with other fundamental excitations in magnetic solids is discussed in the contribution by M. Dvornik et al.

The third section of the book is devoted to magnon spintronics, or interactions between magnons and spin-polarized electrons. The contribution of H. Adachi and S. Maekawa deals with the spin Seebeck effect that enables thermal injection of spin currents from a ferromagnet into adjacent non-magnetic metal. C. Burrowes and B. Heinrich study the spin pumping at the boundary between the magnetic insulator and non-magnetic metal and compare it with similar process at the boundary between the ferromagnetic and non-magnetic metals. The chapter authored by O. Prokopenko et al. considers the microwave detectors based on spin-torque nano-oscillator structures operating in a passive regime, while V. Demidov et al. report on the control of spin-torque oscillators working in the active generating regime by means of external microwave pumping. The final contribution of this section by S. Bonetti and J. Akerman discusses spin-torque nano-oscillators as building blocks for future active nano-spintronic structures and devices.

The fourth section of the book is devoted to artificial periodic structures supporting magnon propagation – static and dynamic magnonic crystals. The chapter by S. Neusser et al. reports on the experimental study of on two-dimensional static magnonic crystals formed by antidotes (or holes) in a Permalloy film, while the chapter by G. Gubbiotti et al. compares properties of two-dimensional magnonic crystals based on magnetic dots and antidotes. The theory of normal magnonic modes in a waveguide based on a static magnonic crystal is presented in the chapter authored N.Yu. Grigoryeva and B.A. Kalinikos and, finally, the theoretical and experimental properties of dynamic magnonic crystals are discussed in the contribution by A. Chumak et al.

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Magnonics

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